FINAL REPORT

IMPROVING MANAGEMENT OF CONTAINER AND FIELD GROWN NURSERY STOCK USING INNOVATIVE TECHNIQUES

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Prepared by: Saskatchewan Nursery Trades Association

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Title

Improving Management of Container and Field Grown Nursery Stock Using Innovative Techniques

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Improving Management of Container and Field Grown Nursery Stock Using Innovative Techniques

A. Summary

The nursery industry is one of the most rapidly growing sectors horticulture. In order to compete effectively with out-of province suppliers and with mass marketers, growers need to adopt techniques that will increase quality and/or reduce production costs. The three techniques under evaluation were 1) foliar feeding of caliper trees to accelerate growth, 2) timing and frequency of shearing of containerized shrubs to promote 'shrubbiness', and 3) developing dormancy management strategies for field-grown trees through the use of plant growth regulators and defoliants.

Foliar feeding – Clonally propagated amur maples, established in 1998, were subdivided into three subgroups. Subgroup 1 was used to assess the effect of supplementing soil-applied nitrogen with foliar applied nitrogen (as urea) on seasonal growth. There was no difference among treatments with respect to caliper increase, fresh weight, date of leaf drop and budbreak. There was a significant amount of winter kill which was likely the result of excess nitrogen nutrition. In the greenhouse dormancy trials and in literature reports, excess nitrogen nutrition has been shown to delay or reduce hardiness development. Subgroup 2 was used to assess the effect of applying a late-fall foliar application of nitrogen (as urea) to supplement nitrogen reserves stored in the bark, wood and roots. Due to high winter kill levels, again as a consequence of elevated nutrient status, no treatment effects were apparent. There were trends, although not statistically significant, that suggested that this may be an area that future research should investigate. Subgroup 3 was used in the Dormancy Management field studies (see below).

Pruning – Shrubs that exhibit a strong tendency towards strong apical dominance will respond to an early to mid-July pruning. Otherwise, shrubs grown under prairie conditions only require pruning at potting up, provided that they receive adequate space, water, nutrients and weed management throughout the growing season.

Dormancy Management –Exogenously applied thidiazuron (TDZ) reduced the delay in dormancy acquisition caused by high fertility to that of control levels (normal fertility) in

dogwood plants. There were undesired side effects such as nodal swelling and bud necrosis. Reducing the frequency and concentration of TDZ advanced VM acquisition in normal fertility treatments but actually delayed VM acquisition even further in the high fertility treatments. Hardiness (timing?) levels increase as trees age; TDZ may have potential for protecting physiologically young trees in the nursery provided that they enter the fall with a normal (rather than high) nutrient status. The field study demonstrated this clearly as the TDZ + high fertility treatment sustained elevated winter kill levels compared to the high fertility control treatment (similar results as in the greenhouse trials). Growers should not look for a chemical quick fix for inappropriate nutrition management. Rather, they should fertilize their crop to ensure that it enters the fall with a nutrient status that is receptive to environmental cues (e.g. short days, cooler nights) allowing them to develop sufficient hardiness in a timely fashion.

Future Research:

Foliar feeding is still an area where there are many questions and potential for increasing growth under prairie conditions. In particular, late foliar feeding showed some promise in accelerating growth in the season following application but due to the high rate of winter kill, significant results were obscured.

Dormancy is strongly influenced by nutrient status and dormancy acquisition may be delayed or prevented from occurring if the nutrient status is too high prior to environmental queuing (i.e. short days, cold nights, etc.). Therefore, investigating timing of fertilizer (soil applied) application and fertilizer rates appropriate for prairie growing conditions should be of high priority.

B. Background

The Saskatchewan growing season is short when compared to more favourable areas of the country. Tree and shrub growth is slow to start in the spring and plants begin to go dormant in early fall leaving only a maximum of 3 months of good growth per season. This results in a long production cycle and therefore a high cost of production when compared to areas such as British Columbia and Ontario. Mass marketers such as

Superstore, Zellers and Price-Costco import lower cost, out-of province (in some cases out-of-country) product to sell to the Saskatchewan consumer.

In order to reduce the amount of time and other inputs required to produce a high quality product under Saskatchewan growing conditions and to reduce imports, growers need techniques which will maximize growth under prairie conditions. Specifically, growers need production tools that will increase the rate of growth of field stock (caliper trees), increase the rate of growth and quality of containerized shrubs, and allow producers to manage dormancy. Trees grown under high fertility conditions should enter dormancy early enough to avoid winter injury and begin growth late enough in the spring to avoid late spring frosts.

Three studies were conducted to address these issues:

1. Determine the correct timing and concentration of foliar nutrient sprays to supplement soil fertility to accelerate the growth of trees throughout the season. Because the growing season is so short, every advantage in growth gained through increased fertility could reduce the typical four to six year production cycle and therefore reduce overall production costs. Treatments focused on nitrogen rates.

A second foliar study evaluated the effects of late fall foliar fertilization. A late application may stimulate the formation of bark storage proteins that may have positive consequences on winter survival and early spring vigor. Initial budbreak and shoot growth depends on remobilization of protein reserves stored in the bark. Foliar treatment will be applied after terminal bud-set and before leaves change colour or drop.

2. Determining the correct timing and degree of shearing of containerized shrubs to stimulate lateral shoot development (= shrubbiness), compactness and overall quality. Typically, containerized shrubs are sheared once at planting and potentially once more just prior to sale to remove dead or unsightly branches. Many species will not respond sufficiently to this minimal approach to develop into a high quality product. One strategy to overcome this problem is to plant two or three rooted cuttings per container, but this

may be a waste of time and resources if better pruning techniques could be developed and adopted by the industry.

3. Develop dormancy management strategies of field grown trees through the use of plant growth regulators and defoliants. The dormancy processes of trees grown under high fertility conditions are disrupted and normally hardy trees may not be dormant enough to survive the onset of winter. Abscisic acid (ABA), a naturally occurring plant growth regulator, has been associated with the dormancy process. Until recently, field application of ABA has been prohibitively costly and so most ABA studies that have been published are typically lab or greenhouse studies (small scale). [The only company producing a low-cost ABA product has withdrawn their product therefore ABA was withdrawn from this study.] Thidiazuron (TDZ) is commercially available as Dropp (AgrEvo) and is used as a defoliant for cotton. Among its many properties, it has been shown to induce endogenous ABA synthesis and to promote dormancy acquisition. Ethylene is another naturally occurring plant growth regulator. Ethrel and Ethephon are two commercial preparations of ethylene which are already used in the greenhouse, fruit & vegetable and nursery industries. In parts of the US, ethylene is used in the fall as a defoliant. Studies indicate that timing and concentration is very important. Ethylene application has not been reported to affect the onset of dormancy, however fall application has been shown to delay spring bud-break by up to a week. The main objective of this project was to manage growth and since spring frosts are unpredictable, a delay in the onset of growth in the spring would also be advantageous.

C. Objectives

The main objective of this project is to assess or provide new and innovative management tools and techniques for the Saskatchewan nursery growers, allowing them to become more competitive with out-of province nursery suppliers. This will help stimulate an already growing sector of the horticulture industry in Saskatchewan. These same management tools could also benefit the fruit growers of the province, since they face many of the same environmental challenges as the nursery growers.

D. Activities

1. Foliar Feeding

One hundred forty-four (144) clonally propagated amur maples (*Acer ginnala;* six-month rooted cuttings) were established in the field (U of S Horticulture research plots) in August 1998 under drip irrigation and black plastic mulch. This group of maples was divided into three subgroups for three separate trials: 1) foliar feeding throughout the season, 2) fall foliar feeding and 3) dormancy management (see section 3. Dormancy management: field trial for third maple trial). All maples were fertilized via drip irrigation with 84 kg nitrogen/ha (75 lb. nitrogen/acre) from 20-20-20 + micronutrients two times during the growing season (May 28 and August 3, 1999) to satisfy soil fertility requirements.

Trial #1: Foliar feeding for supplemental nitrogen application throughout the season

All the reported foliar fertilization trials relevant to woody plants have been conducted on fruit (e.g. apple, peach, nectarine, peach, avocado, citrus) and nut (e.g. almond) crops (Swietlik & Faust, 1984). This is likely a result of their economic importance as increases in yield per area by increased management impacts directly on profitability. Since much of the research looks at nitrogen absorption, mobilization and use, it is generally applicable to woody ornamental production management.

Urea is the preferable nitrogen source for foliar feeding as it is less damaging to leaves than other nitrogen forms (Swietlik and Faust, 1984), and foliar urea sprays have been recommended since the 1950's and 1960's for apple (Oland, 1963; Oland 1960; Cook and Boynton, 1952). Absorption is very rapid with 70 – 85% of applied urea absorbed by the leaf within 48 hours (Zilkah et al., 1987; Klein and Weinbaum, 1984; Fisher, 1952).

The rate of uptake is affected by a number of factors. First, both plant species and leaf age affects the rate and amount of uptake (Price and Anderson, 1985) which probably reflects differences in leaf characteristics. Urea can be absorbed by both the upper and lower leaf surfaces, but is, by far, more rapidly absorbed by the lower (Cook and

Boynton, 1952; Rodney, 1952). This suggests that urea can penetrate cuticular waxes and enter the leaf directly through the epidermis as well as through the stomata (Swietlik and Faust, 1984; Cook and Boynton, 1952) and therefore wax characteristics and stomatal distribution and number can affect absorption. Second, environmental factors can affect absorption. Cook and Boynton (1952) found that relatively low temperature (< 30° C) and low vapour pressure deficit (i.e. high relative humidity) enhanced absorption. This is likely due to the length of time that the urea solution is allowed to remain in an aqueous state: the lower the pressure to evaporate, the longer the leaf has a chance to absorb nitrogen.

Third, solution characteristics can also affect nutrient absorption. Solution pH can have a large effect on absorption. Cook and Boynton (1952) found that a low pH (5.6 – 6.8) resulted in higher uptake of urea than neutral or basic pH. They also found that adding a surfactant, in this case Tween 20 or 80, doubled uptake over a 2 –5 hour period. Adding a surfactant ensures that the spray does not form droplets on the leaf, but rather tends to form a film over the leaf, thus maximizing surface coverage and increasing the chance of cuticular penetration and reducing the chance of concentrated nutrient spot damage from occurring. Furthermore, it has been suggested that surfactants can improve absorption of foliar applied chemicals through the stomata (Swietlik and Faust, 1984). Others have found that surfactants do not affect nutrient absorption by the leaf (Klein & Weinbaum, 1985; Leece and Dirou, 1977), but Tween has not been used in these trials. It is hypothesized that since urea is such a small non-polar molecule, it can easily and rapidly penetrate through the leaf surface without the aid of a surfactant (Weinbaum, 1988).

Redistribution within the plant of foliar applied nitrogen depends on two factors. Firstly, the timing of spray(s) affects remobilization. If applied early in the year, the nitrogen tends to stay primarily in the leaf (Hill-Cottingham and Lloyd-Jones, 1975) but can also be transported short distances to vegetative and reproductive sinks (Weinbaum, 1988; Zilkah and Feigenbaum, 1987; Klein and Weinbaum, 1984). If applied later in the year (i.e. post-harvest in the case of fruit crops, 3 – 4 weeks before leaf-drop for other woody plants), nitrogen tends to be rapidly exported to perennial storage organs (e.g. bark, wood

and roots) (Rosecrance et al., 1998a, b; Zilkah and Feigenbaum, 1987). Secondly, nutrient status affects translocation. If there is a nutrient deficiency, leaf applied nitrogen tends to remain in the leaf and very little is translocated to developing sinks (Weinbaum, 1988). Nutrient status does not in itself, however, represent a barrier to absorption rate or amount absorbed.

Foliar application has been estimated to be as much as four times more efficient at supplying nutrients to a plant than soil application (Shim et al., 1972). Furthermore, a much faster response to fertilizer application occurs from applying fertilizer via the leaves than via the soil (Fisher, 1952). However, due to the relatively small amount of nutrient (due to potential damage from excessively high fertilizer salt concentrations) that can be applied at any one time, not all the plant's needs can be satisfied in one season through foliar feeding. Weinbaum (1978) estimated that it would require 140 applications of 1.2% KNO3 per year to maintain normal growth if foliar applied NO_3^- was the only nitrogen source.

Swietlik and Faust (1984) presented a number of recommendations. The most useful recommendation is urea rate that they suggest should be 0.5 – 1.2 kg urea/100 L (4 – 10 lb. urea/100 gal) if applied early in the year (preharvest) and 5 kg urea/100 L (42 lb. urea/100 gal) if applied in late fall (post harvest). Other recommendations include use of surfactants, adjusting solution pH (see above). Also, growers should avoid applying nutrient sprays during high temperature (> 25° C), moderate to high wind (= rapid drying conditions), extremely high humidity (> 80% RH) conditions and to also avoid spraying plants under stress (particularly drought) (Schupp, 1993). This argues that spraying should occur in the late afternoon.

In developing the treatments for the trial, we have adopted some of the recommendations from Swietlik and Faust (1984).

Materials & Methods

Treatments:

1) Control (water)
2) 2% nitrogen (as urea)
3) 4% nitrogen (as urea)

Species: Amur maple (*Acer ginnala*)

Growing site: University of Saskatchewan Plant Science research plots (14th Street Research Plots, Block 5, Saskatoon: clay soil)

Reverse osmosis water was used to prepare all spray solutions; all treatments were supplemented with 0.1% Tween 20 to ensure complete foliar coverage and to enhance nutrient uptake. Solution pH was consistently 5.9 - 6.1 and no pH adjustments were made. Foliar sprays were applied using CO_2 pressurized sprayer until foliage was wet and just dripping. The first treatment was applied on June 16, 1999 when leaves were fully expanded. Due to weather, further applications were not possible until July 8, 1999, after which time treatments were applied weekly until August 27, 1999 (nine times in total). In 2000, treatments were applied weekly starting from June 14 and ending on August 24 (11 times in total).

Statistical Analysis

Treatments were arranged in a Completely Randomized Block Design. The field has a slight slope and blocks were arranged against the slope to minimize error variability. There are four replicates with 3 trees per treatment. Since the trees were clones from a single plant, between plant variation was minimized. Caliper measurements were taken on May 26 1999, September 10 1999, and October 30 2000. Aboveground growth was harvested on October 30 2000 after leaf fall and fresh weight was recorded. Data was tested using ANOVA with initial caliper measurement used as a covariate to reduce error variability. Treatment means were compared with LSD (Fisher's protected) and trend analysis was performed using orthogonal contrasts.

Results

There were no significant differences among treatments nor were there any significant trends with respect to caliper increase and nitrogen rate in the first year (Table 1). There was substantial winter dieback during the 1999/2000 winter. While there was a great deal of regrowth during the season, Coefficient of Variation (CV%) was dramatically increased from 9.24 to 37.1 for caliper increase from 1999 to 2000. Date of 50% and 100% budbreak was not affected by treatment (data not shown). Budbreak only occurred on the portion of the tree that had been protected by snow. There were no significant differences among treatment with for fresh weight or caliper development nor were there any significant trends (Table 1).

Discussion

All trees exhibited a great deal of growth in their first year. The lack of differences among treatments in the first year (1999) should not be surprising since the trees were neither water nor nutrient stressed at any time during the growing season. Also, trees are most productive in terms of biomass production when they are young.

The high level of winterkill during 1999/2000 may have obscured any results from the second season (2000). It is possible that the nutrient status may have been elevated from soil applied nutrients during the first season. Two plants that were at the end of adjacent rows suggested that this might have been the case. These trees exhibited chlorosis in 1999 and 2000, had reduced caliper development but did not suffer any winter dieback. These were the only trees that survived completely unscathed. The reason why these trees suffered from chlorosis is not clear but may be related to extremely localized elevated soil pH conditions (i.e. alkaline condition), which would have limited nutrient availability. In a recent study by Jalkanen et al., (1998), nutrient deficiencies have been shown to actually increase winter hardiness. This is not a practice, however, that should be adopted because nutrient deficiencies will reduce growth and quality and if taken too far, will reduce ultimate survival.

This suggests that timing of nutrient application is critical in our short season environment and that fertilizer should be applied only in the spring, once soils have warmed up and budbreak has occurred. Timing of ground-applied fertilizer should be an area of future research as there are no current recommendations for prairie conditions. There were no indications that foliar applied nutrients provided any benefit to growth rate.

Table 1. The effect of applying a 0 (water control), 2 or 4% nitrogen (as urea) weekly foliar spray from June to the end of August (in both 1999 and 2000) on fresh weight, caliper and winterkill of two year-old clonally propagated amur maples (*Acer ginnala*) grown at the Univ. of SK Plant Sciences (horticulture) plots.

Treatment	Fresh weight (kg)[a]	Pre-treatment caliper (mm) spring, 1999	Caliper increase from spring 1999 to fall 1999 (%)	Caliper increase from spring 1999 to fall 2000 (%)	Winterkill (%) (1999/2000)[a,b]
Control	0.46	9.84	45.73	140.5	51.2
2% N (Urea)	0.48	8.73	47.39	166.8	50.4
4% N (Urea)	0.53	8.27	43.89	152.2	50.7
Statistical Analysis					
Significance[c]	ns		ns	ns	ns
LSD	-		-	-	-
CV%	42.0		9.24	37.1	32.5

a – initial caliper measurements used as covariate in GLM analysis
b – percent data was transformed using the arcsine transformation method; non-transformed averages presented, but significance, LSD and CV% are calculated from transformed data
c – ns = not significant

Trial #2: Fall foliar feeding to boost nitrogen reserve to enhance early spring growth.

Nitrogen is exported from the leaf in the fall to perennial storage organs such as bark, wood and roots (Rosecrance et al., 1998a, b; Sanchez et al., 1990; Kang et al., 1982). This remobilization begins 3 – 4 weeks before leaf-fall (O'Kendedy et al., 1975; Oland, 1963; Oland, 1960). Nitrogen is stored in protein form and stored in bark (=> bark storage proteins = bsp) or in soluble forms in wood. In the spring, reserve nitrogen is used in earliest growth (vegetative and reproductive bud break) (Sweitlik and Faust, 1984; Weinbaum et al., 1984); this is an adaptive mechanism since early spring soil temperatures severely restrict root absorption of nutrients (Hill-Cottingham and Lloyd-Jones, 1975). The soluble nitrogen stored in the wood is the first nitrogen form to be used, followed by rapid and massive breakdown of the bsp's yielding up more of the stored nitrogen (Kang et al., 1982) to support early growth.

Fall foliar nitrogen (in the form of urea) sprays have been shown to increase the amount of stored nitrogen throughout the tree (Rosecrance et al., 1998a, b; Weinbaum et al., 1984; Sanchez et al., 1990; Hill-Cottingham and Lloyd-Jones, 1975; Oland, 1963; Oland, 1960). Shim et al. (1972) demonstrated that senescing apple leaves were able to absorb 75% of the applied urea (5% solution) spray, which resulted in significantly higher shoot

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2% N (Urea)	0.48	8.73	47.39	166.8	50.4
4% N (Urea)	0.53	8.27	43.89	152.2	50.7
Statistical Analysis					
Significance[c]	ns		ns	ns	ns
LSD	-		-	-	-
CV%	42.0		9.24	37.1	32.5

a – initial caliper measurements used as covariate in GLM analysis
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Fall foliar nitrogen (in the form of urea) sprays have been shown to increase the amount of stored nitrogen throughout the tree (Rosecrance et al., 1998a, b; Weinbaum et al., 1984; Sanchez et al., 1990; Hill-Cottingham and Lloyd-Jones, 1975; Oland, 1963; Oland, 1960). Shim et al. (1972) demonstrated that senescing apple leaves were able to absorb 75% of the applied urea (5% solution) spray, which resulted in significantly higher shoot

growth and fruit set the following spring. Older leaves are much more tolerant of high urea concentration than younger leaves. In fact, mature leaves (senescing) can tolerate as high as a 10% urea solution with little damage to the leaf and without any reduction in absorption capacity (Sanchez et al., 1990).

None of the published trials reported that vegetative growth recommenced following post-harvest urea application. This should not be surprising since once trees have started acclimating and vegetative maturity (VM) acquisition is complete (VM is the first stage of significant bud dormancy), natural bud-break can only occur after a chilling requirement has been satisfied. This points to the fact that timing of foliar nitrogen application is critical: if it occurs before VM is acquired, dormancy (and hardiness) may be delayed or disrupted and growth may resume. In one reported case, cold tolerance was reduced in the late fall/early winter by a few degrees, but by mid-winter, cold tolerance in these same urea treated trees was higher than controls (Raese, 1997). The explanation for the temporary reduction in hardiness following urea application is not that dormancy processes were reversed but that leaf longevity and functionality was extended to process and export the additional nitrogen. Once the nitrogen was transported out and leaves were in a nitrogen low state, normal hardening processes continued. The higher cold tolerance in the late winter is a reflection of the tree's improved nitrogen status.

Recommendations for Fall Foliar Urea Application†

1. Best growth is achieved if tree is supplied with adequate nitrogen nutrition throughout the season + fall foliar urea application in late fall to boost nitrogen reserves for early spring growth.
2. Fall foliar urea application should be delayed until 2 – 3 weeks before natural leaf drop.
3. Urea concentrations can be as high as 5% urea without reducing absorption capacity although some leaf damage (tip burn or edge necrosis) may be evident.

† based on Khemira et al., 1998; Swietlik and Faust, 1984; Weinbaum, 1984; O'Kennedy et al., 1975; Oland, 1963; Oland, 1960

A number of recommendations have been developed for fruit growers who wish to manage their crop more effectively (see side box). Most of the recommendations should be applicable to woody ornamental producers for two reasons. First, many of the woody ornamentals that are grown are closely related to the fruit crops for which fall foliar urea

application has proved beneficial (e.g. directly related = pear, apple, crabapple; closely related = mountain ash, butternut, chokecherry, mayday, amur cherry, hawthorn, etc.). Second, while there is a great deal of diversity among hardy trees, there is also a great deal of commonality among physiological processes. This should include responses to late season foliar applied urea. Differences will occur mainly in tolerance to high urea concentrations (> 5% urea) and degree of absorption.

This trial evaluated the effect of an early and late fall foliar urea application on amur maple on various caliper, fresh weight and winter survival.

Materials & Methods

Treatments:

1. control (water) applied on September 10 1999 (early) and October 6 1999 (late)
2. early application of foliar applied 4% nitrogen (as urea)
3. late application of foliar applied 4% nitrogen (as urea)
4. both early and late application of foliar applied 4% nitrogen (as urea)

Species:

Amur maple (*Acer ginnala*)

Growing site:

University of Saskatchewan, Dept. Plant Science research plots (14th Street Research Plots, Block 5, Saskatoon: clay soil)

Reverse osmosis water was used to prepare all spray solutions; all treatments were supplemented with 0.1% Tween 20 to ensure complete foliar coverage and to enhance nutrient uptake. Solution pH was consistently 5.9 - 6.1 and no pH adjustments were made. Foliar sprays were applied using CO_2 pressurized sprayer until foliage was wet and just dripping.

Statistical Analysis

Treatments were arranged in Completely Randomized Block Design. The field has a slight slope and blocks were arranged against the slope to minimize error variability. Since the trees are clones from a single plant, between plant variation is minimized. Caliper measurements were taken on May 26 1999, October 15 1999 and October 30 2000. Above ground growth was harvested on October 30 2000 and fresh weight of each tree was determined. Treatments were evaluated with respect to date of budbreak and winter survival. Data was tested using ANOVA with initial caliper measurement used as a covariate to reduce error variability. Winter survival data was transformed using the arcsine transformation method, as appropriate for percentage data, before performing ANOVA. Treatment means were compared with LSD (Fisher's protected).

Results

There was no difference among treatments for date of 50% leaf drop (October 15, 1999) or 100% leaf drop (October 29, 1999) (data not shown). There was no difference among treatments with respect to caliper increase or fresh weight (Table 2).

Discussion

There was no expectation that caliper development would be affected in fall 1999 by the foliar application. Caliper growth is a result new tissue deposition (cell division and growth), not storage of nitrogenous compounds. Based on Raese (1997), it would not have been surprising if date of leaf drop was affected by foliar urea treatments. However, Raese based his experiments on 'D'Anjou' pear, a tree that is not hardy for this area, and likely does not respond as quickly to short days as the hardier amur maple that was used here. Also, as previously noted, there are differences among species and cultivars with respect to specific effects and timing of events but not general physiological events (i.e. each hardy tree species reaches dormancy at its own pre-determined pace, influenced by local environmental conditions).

The high incidence of winter dieback was likely due to an elevated nutrient status in the plants from ground applied fertilizer (see reasoning in first trial). This dieback would

have obscured any treatment results. There is a slight but non significant increase in fresh weight in treatments over that of control but due to the high level of variation (due to > 80% winter dieback), nothing more can be said on this aspect. As a result, no recommendations can be made regarding late season foliar nitrogen applications.

Table 2. The effect of applying an early fall (Sept. 10, 1999), late fall (Oct. 6, 1999), or both an early and late fall 4% nitrogen (as urea) foliar spray on the caliper growth, fresh weight and winter survival of two year-old clonally propagated amur maples (*Acer ginnala*) grown at the Univ. of SK Plant Sciences (horticulture) plots.

Treatment	Fresh weight (kg)[a]	Pre-treatment caliper (mm) spring 1999	Caliper increase from spring 1999 to fall 1999 (%)	Caliper increase from spring 1999 to fall 2000 (%)	Winterkill (%) (1999/2000)[a,b]
Control	0.54	9.77	58.97	201.1	88.6
Early	0.64	10.07	58.10	186.4	85.2
Late	0.69	10.09	59.22	211.6	87.5
Early + Late	0.77	8.23	72.53	205.3	83.8
Significance[c]	ns		ns	ns	ns
LSD	-		-	-	-
CV%	24.5		19.3	25.8	9.5

a – initial caliper measurements used as covariate in GLM analysis

b – percent data was transformed using the arcsine transformation method; non-transformed averages presented, but significance, LSD and CV% are calculated from transformed data

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Early	0.64	10.07	58.10	186.4	85.2
Late	0.69	10.09	59.22	211.6	87.5
Early + Late	0.77	8.23	72.53	205.3	83.8
Significance[c]	ns		ns	ns	ns
LSD	-		-	-	-
CV%	24.5		19.3	25.8	9.5

a – initial caliper measurements used as covariate in GLM analysis

b – percent data was transformed using the arcsine transformation method; non-transformed averages presented, but significance, LSD and CV% are calculated from transformed data

c – ns = not significant

2. Mechanical Pruning Evaluation

Typically, containerized shrubs are sheared once at planting and potentially once more just prior to sale to remove dead or unsightly branches. Most species will not respond well enough to this minimal approach to develop into a high quality product. One strategy to overcome this problem is to plant two or three rooted cuttings per container, but this is clearly a waste of time and resources if better pruning techniques could be developed and adopted by the industry.

1998 trial:

Materials & Methods

Treatments*:

1. Control (prune only at potting up)
2. Prune 1 time (late season)
3. Prune 2 times (early and late season)
4. Prune 3 times (monthly)

* all treatments were pruned at potting up

Species:

Cistena cherry (*Prunus* x *cistena*)

Meyer lilac (*Syringa meyeri*)

Nanking cherry (*Prunus tomentosa*)

Sites:

Dutch Growers Garden Centre Ltd. (container production farm – Beaver Creek)

Lakeshore Tree Farms Ltd. (container production farm – 11th Street W.)

Statistical analysis

All treatments including control were pruned at potting up (Dutch Growers on May 13, 1998 and Lakeshore on May 9, 1998) to a standard height (15 cm = 6 in for all species except Lakeshore Meyer lilac which was pruned to 20 cm = 8 in). There were 5

replicates with 4 plants per replicate per species. Treatments were arranged in a Completely Randomized Block Design (CRBD).

Results

Treatments were to begin on June 1; however, very little growth had occurred at this time and treatments were delayed until June 29. **June 29 (early season)**: Treatments 3 (2 times) and 4 (monthly) were pruned. At Dutch Growers, Meyer lilac and nanking cherry were pruned to 20 cm (8 in). Cistena cherry had not put on much growth and therefore only the shoot tips were removed. At Lakeshore, Meyer lilac and cistena cherry were pruned to 20 cm (8 in) and nanking cherry to 30 cm (12 in). **August 4 (mid-season)**: Treatment 4 was pruned, at which time, the top 5 cm (2 in) were removed from all plants in the treatment group at both sites. **August 31 (late season)**: Treatments 2 (one time), 3 (two times) and 4 (monthly) were pruned. As with the previous pruning time (August 4), the top 5 cm (2 in) were removed from each plant at both sites. Most of the cistena cherries were sold accidentally in August 1998 at Lakeshore and was therefore removed from the trial. All remaining plants were put into winter storage at the end of October at both sites. Plants were to be evaluated following budbreak in early spring (June 1999) but due to poor survival at both sites, this evaluation was not possible. No explanation can be forwarded for the poor survival of these three species as the winter was not extreme and the overwintering structures were not different from previous years.

Initial visual evaluations (data not shown) in the 1998 season suggested that some shrubs such as Meyers' lilac with a strong tendency to be multistemmed, do not require additional pruning throughout the season to promote shrubbiness. Other shrubs, such as cistena cherry and nanking cherry, which have a poor to moderate tendency to be multistemmed, require at least one and perhaps two prunings during the growing season. In Figure 1, this is quite evident: the control treatment is very tall (relative to the other treatments) and poorly branched, whereas the next two treatments (June and June & August pruning) are better branched and more compact. The last treatments (montly pruning) is well branched but too short. The growing season is not long enough for shrubs to respond to three prunings in one year.

Figure 1. Pruning trial visual results of Cistena sandcherry (1998). From left to right: control (pruned only at potting up), June pruning, June & August pruning and monthly pruning.

2000 trial:

Materials & Methods

Treatments*:

1. Control (prune only at potting up)
2. Prune in June
3. Prune in July
4. Prune in August
5. Prune in June & July
6. Prune in June & August
7. Prune in July & August

* all treatments were pruned at potting up

Sites:

1. Dutch Growers Garden Centre Ltd. (container production farm – Beaver Creek)
2. Lakeshore Tree Farms Ltd. (container production farm – 11th Street W.)

Species:

Site 1: Cistena cherry (*Prunus* x *cistena*)
Diablo ninebark (*Physocarpus opulifolius* 'Diablo')
Adelaide Hoodless rose (*Rosa* x 'Adelaide Hoodless')

Site 2: Variegated dogwood (*Cornus alba* '*Elegetissima*')
Therese Bugnet rose (*Rosa* x 'Therese Bugnet')
American highbush cranberry (*Viburnum trilobum*)

All plants were pruned initially at potting up to a standard height (May 15). Pruning occurred on June 17, July 24 and August 17. Pruning consisted of bunching up the branches and removing the top 5 cm (2 inches) of growth. On each pruning date, all buds, open flowers and hips were removed from all rose treatments. Evaluation for appearance (as defined by the Canadian Nursery Standards) and saleability were evaluated on October 6 after the first major frost (Sept 23). This allowed better evaluation of the shrub form as most of the leaves were knocked off or dried up. The plants were evaluated on a scale of 1 to 3 where plants rated 1 or 2 were salable and plants rated 3 were unsalable. Figures 2a – d show the visual types used for each rating value. Salability data was tested with Chi-squared (χ^2) as this is the most appropriate analysis for binomial data. The number of stems formed below 10 cm, height and height x width were tested with ANOVA and treatment means were compared with LSD (Fisher's protected).

Results:

Dutch Growers Garden Centre: Salability was significantly affected by pruning treatment for Cistena sandcherry (CS) and Adelaide Hoodless Rose (AHR) but Diablo ninebark (DN) was unaffected. In the case of CS, pruning once at any time during the season

resulted in significantly ($p \leq 0.01$) more salable plants than pruning two times in the season. However, a one-time pruning was no more effective than control in producing salable plants. On average, pruning AHR once at any time during the season produced significantly ($p \leq 0.05$) more salable plants than control but was not more effective than pruning twice. Pruning once either in July or August produced significantly ($p \leq 0.01$) more salable plants than pruning in June (Table 3a).

Height was significantly ($p \leq 0.01$) affected by pruning treatment for CS and DN. Treatment differences in AHR were only apparent in the orthogonal contrast analysis. The height of CS was significantly shorter ($p \leq 0.01$) after pruning twice than after pruning once which was in turn significantly ($p \leq 0.01$) shorter than control. Pruning in July resulted in significantly ($p \leq 0.05$) shorter plant than pruning in June. For AHR, pruning in June or August resulted in significantly ($p \leq 0.10$ or 0.01, respectively) shorter plants than pruning in July. The height of DN was more affected by treatment than CS or AHR. Pruning twice produced significantly ($p \leq 0.01$) shorter plants than pruning once which in turn were on average significantly ($p \leq 0.01$) shorter than control. Plants became progressively shorter the later that they were pruned, where July pruning produced significantly ($p \leq 0.10$) shorter plants than June pruning and August pruning produced significantly shorter plants than June or July pruning ($p \leq 0.01$ or 0.05, respectively) (Table 3b).

The number of stems formed below 10 cm (4 inches) or the height x width were not affected by pruning treatment (data not shown).

Lakeshore Tree Farms: Salability of variegated dogwood (VD) and Therese Bugnet rose (TBR) was significantly ($p \leq 0.01$) affected by pruning treatments. None of the American cranberry (AC) reached salable size because they ceased growth and set terminal buds very early in the season (June) and pruning did not stimulate growth or branching. In the case of VD, control treatment produced significantly ($p \leq 0.05$) more salable plants than pruning once at time during the season. However, pruning once

during the season did not result in any more salable plants than pruning two times. TBR was not very responsive to pruning, but pruning once was significantly ($p \leq 0.05$) more effective than pruning twice in producing salable plants. This was due to the fact that pruning in both July and August greatly impacted quality. When the analysis was repeated with the July + August pruning data removed, pruning once is no more effective than pruning twice in producing salable plants (Table 4a).

Height was significantly ($p \leq 0.01$) affected by pruning treatment. For VD, pruning twice produced significantly ($p \leq 0.01$) shorter plants than pruning once but was itself no more effective than control. Pruning in August produced significantly shorter plants than pruning in June or July ($p \leq 0.05$ or 0.10, respectively). The height of TBR was greatly affected by pruning. Pruning twice resulted in significantly ($p \leq 0.01$) shorter plants than those pruned once which were in turn significantly ($p \leq 0.01$) shorter than control. Plants pruned in July or August were significantly ($p \leq 0.01$) shorter than those pruned in June. The height of AC was affected similarly to TBR. Pruning twice resulted in significantly ($p \leq 0.01$) shorter plants than those pruned once which in turn were significantly ($p \leq 0.01$) shorter than control. Pruning in July or August produced significantly ($p \leq 0.01$ or 0.05, respectively) shorter plants than those pruned in June (Table 4b).

The number of stems formed below 10 cm (4 inches) or the height x width were not affected by pruning treatment (data not shown).

Discussion

Two main recommendations can be drawn from the data analysis. First, in four of the five species that reached salable size, control treatment resulted in equal or higher number of salable plants than the one time pruning treatment group. This suggests that pruning shrubs throughout the season under prairie conditions is not necessary and may even reduce quality. Pruning only at potting up is sufficient (for these species) to result in salable plants in one season, provided that enough space, nutrients and water have been supplied. In the case of AHR, this rose shows a strong tendency to be single stemmed

rather than multi branched. Thus this and similar types of plants, a mid-season (July) pruning is effective in producing a salable plant.

The second point that can be drawn for the analysis is that height is inversely proportional to the number of times a shrub is pruned (i.e. the more a shrub is pruned throughout the season, the shorter it becomes). Furthermore, with only one exception, the later a shrub is pruned, the shorter it is at the end of the season. The one exception was again AHR, which was taller in the July pruning group than any of the other treatments. The reason for this is not clear but may be related to the fact that the July group had developed stronger multiple canes than those in the control or June pruning groups and had a higher leaf area surface than other treatments leading to superior growth.

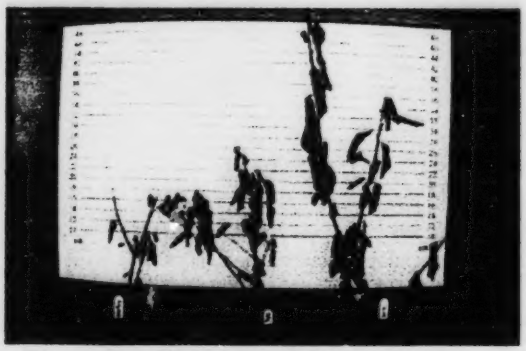

Figure 2a. Cistena sandcherry visual quality evaluation types: from left to right, quality = 3, 2, and 1 where 1 and 2 are salable and 3 is unsalable.

Figure 2b. Diablo ninebark visual quality evaluation types: from left to right, quality = 3, 2, and 1 where 1 and 2 are salable and 3 is unsalable.

Figure 2c. Variegated dogwood visual quality evaluation types: from left to right, quality = 1 and 2 where 1 is salable and 2 is unsalable.

Figure 2d. Therese Bugnet rose visual quality evaluation types: from left to right, quality = 1, 2 and 3 where 1 and 2 are salable and 3 is unsalable.

NOTE: all plants were evaluated after the first major frost

Table 3a. Saleability of Cistena sandcherry, Adelaide Hoodless rose and Diablo ninebark at the end of the season in pruning trials (Dutch Growers Garden Centre)

	Cistena Sandcherry	Adelaide Hoodless Rose	Diablo Ninebark
Pruning Treatment	% saleable	% saleable	% saleable
Control	84.6	31.3	61.1
June	80.0	26.7	66.7
July	80.0	84.6	57.1
August	60.0	84.6	64.3
June & July	53.3	46.7	33.3
June & August	57.1	50.0	78.6
July & August	26.7	53.3	53.3

Statistical Analysis[a,b]	χ^2	signif.	χ^2	signif.	χ^2	signif.
Total	15.6	*	17.9	**	7.1	ns
once vs. twice	7.2	**	1.5	ns	0.6	ns
control vs. once	0.7	ns	4.8	*	0.0	ns
June vs. July	0.0	ns	9.4	**	0.3	ns
June vs. August	1.4	ns	9.4	**	0.0	ns
July vs. August	1.4	ns	0.0	ns	0.1	ns

a – χ^2 analysis performed using actual numbers (i.e. saleable vs nonsaleable) rather than percentages
b – significance of χ^2 values are: ns = not significant; * and ** = significant at $p \leq 0.05$ and 0.01, respectively

Table 3b. Final height of Cistena sandcherry, Adelaide Hoodless rose and Diablo ninebark at the end of the season in pruning trials (Dutch Growers Garden Centre)

	Cistena Sandcherry	Adelaide Hoodless Rose	Diablo Ninebark
Pruning Treatment	Height (cm)	Height (cm)	Height (cm)
Control	45.5	38.1	66.6
June	40.5	36.1	65.2
July	32.3	46.0	57.6
August	36.3	28.1	47.6
June & July	31.1	34.7	45.9
June & August	29.4	34.1	47.4
July & August	24.5	30.7	38.5

Statistical Analysis[a]			
Significance	**	ns	**
LSD	10.6	-	11.0
CV%	30.7	42.4	20.9
Orthogonal Contrasts			
Once vs twice	**	ns	**
Control vs once	**	ns	**
June vs July	*	+	+
June vs August	ns	ns	**
July vs August	ns	**	*

a – ns = not significant; +, * and ** = significant at $p \leq 0.10$, 0.05 and 0.01, respectively

Table 4a. Saleability of variegated dogwood and Therese Bugnet at the end of the season in pruning trials (Lakeshore Tree Farms)

Pruning Treatment	Variegated Dogwood % saleable	Therese Bugnet Rose % saleable
Control	87.7	93.8
June	64.3	93.3
July	50.0	78.6
August	30.0	100.0
June & July	81.8	93.3
June & August	15.3	78.6
July & August	26.7	38.5

Statistical Analysis[a,b]	χ^2	signif.	χ^2	signif.
Total	24.7	**	25.7	**
once vs. twice	1.0	ns	5.4	*
control vs. once	6.0	*	0.1	ns
June vs. July	0.6	ns	1.3	ns
June vs. August	2.7	ns	1.0	ns
July vs. August	1.0	ns	3.5	ns

a – χ^2 analysis performed using actual numbers (i.e. saleable vs nonsaleable) rather than percentages
b – significance of χ^2 values are: ns = not significant; * and ** = significant at $p \leq 0.05$ and 0.01, respectively

Table 4b. Final height of variegated dogwood, Therese Bugnet rose and American cranberry at the end of the season in pruning trials (Lakeshore Tree Farms)

Pruning Treatment	Variegated Dogwood Height (cm)	Therese Bugnet Rose Height (cm)	American Cranberry Height (cm)
Control	35.9	40.1	19.6
June	35.0	42.9	16.3
July	33.9	30.9	11.6
August	30.3	29.6	12.7
June & July	27.8	29.2	10.5
June & August	32.4	34.7	9.3
July & August	26.4	26.9	8.4
Statistical Analysis[a]			
Significance	**	**	**
LSD	5.9	6.5	4.6
CV%	18.6	20.2	37.6
Orthogonal Contrasts			
Once vs twice	**	**	**
Control vs once	ns	**	**
June vs July	ns	**	**
June vs August	*	**	*
July vs August	+	ns	ns

a – ns = not significant; +, * and ** = significant at $p \leq 0.10$, 0.05 and 0.01, respectively

Table 3a. Saleability of Cistena sandcherry, Adelaide Hoodless rose and Diablo ninebark at the end of the season in pruning trials (Dutch Growers Garden Centre)

Pruning Treatment	Cistena Sandcherry % saleable	Adelaide Hoodless Rose % saleable	Diablo Ninebark % saleable
Control	84.6	31.3	61.1
June	80.0	26.7	66.7
July	80.0	84.6	57.1
August	60.0	84.6	64.3
June & July	53.3	46.7	33.3
June & August	57.1	50.0	78.6
July & August	26.7	53.3	53.3

Statistical Analysis[a,b]	χ^2	signif.	χ^2	signif.	χ^2	signif.
Total	15.6	*	17.9	**	7.1	ns
once vs. twice	7.2	**	1.5	ns	0.6	ns
control vs. once	0.7	ns	4.8	*	0.0	ns
June vs. July	0.0	ns	9.4	**	0.3	ns
June vs. August	1.4	ns	9.4	**	0.0	ns
July vs. August	1.4	ns	0.0	ns	0.1	ns

a – χ^2 analysis performed using actual numbers (i.e. saleable vs nonsaleable) rather than percentages
b – significance of χ^2 values are: ns = not significant; * and ** = significant at $p \leq 0.05$ and 0.01, respectively

Table 3b. Final height of Cistena sandcherry, Adelaide Hoodless rose and Diablo ninebark at the end of the season in pruning trials (Dutch Growers Garden Centre)

Pruning Treatment	Cistena Sandcherry Height (cm)	Adelaide Hoodless Rose Height (cm)	Diablo Ninebark Height (cm)
Control	45.5	38.1	66.6
June	40.5	36.1	65.2
July	32.3	46.0	57.6
August	36.3	28.1	47.6
June & July	31.1	34.7	45.9
June & August	29.4	34.1	47.4
July & August	24.5	30.7	38.5

Statistical Analysis[a]			
Significance	**	ns	**
LSD	10.6	-	11.0
CV%	30.7	42.4	20.9
Orthogonal Contrasts			
Once vs twice	**	ns	**
Control vs once	**	ns	**
June vs July	*	+	+
June vs August	ns	ns	**
July vs August	ns	**	*

a – ns = not significant; +, * and ** = significant at $p \leq 0.10$, 0.05 and 0.01, respectively

Table 4a. Saleability of variegated dogwood and Therese Bugnet at the end of the season in pruning trials (Lakeshore Tree Farms)

Pruning Treatment	Variegated Dogwood % saleable	Therese Bugnet Rose % saleable
Control	87.7	93.8
June	64.3	93.3
July	50.0	78.6
August	30.0	100.0
June & July	81.8	93.3
June & August	15.3	78.6
July & August	26.7	38.5

Statistical Analysis[a,b]	χ^2	signif.	χ^2	signif.
Total	24.7	**	25.7	**
once vs. twice	1.0	ns	5.4	*
control vs. once	6.0	*	0.1	ns
June vs. July	0.6	ns	1.3	ns
June vs. August	2.7	ns	1.0	ns
July vs. August	1.0	ns	3.5	ns

a – χ^2 analysis performed using actual numbers (i.e. saleable vs nonsaleable) rather than percentages
b – significance of χ^2 values are: ns = not significant; * and ** = significant at $p \leq 0.05$ and 0.01, respectively

Table 4b. Final height of variegated dogwood, Therese Bugnet rose and American cranberry at the end of the season in pruning trials (Lakeshore Tree Farms)

Pruning Treatment	Variegated Dogwood Height (cm)	Therese Bugnet Rose Height (cm)	American Cranberry Height (cm)
Control	35.9	40.1	19.6
June	35.0	42.9	16.3
July	33.9	30.9	11.6
August	30.3	29.6	12.7
June & July	27.8	29.2	10.5
June & August	32.4	34.7	9.3
July & August	26.4	26.9	8.4
Statistical Analysis[a]			
Significance	**	**	**
LSD	5.9	6.5	4.6
CV%	18.6	20.2	37.6
Orthogonal Contrasts			
Once vs twice	**	**	**
Control vs once	ns	**	**
June vs July	ns	**	**
June vs August	*	**	*
July vs August	+	ns	ns

a – ns = not significant; +, * and ** = significant at $p \leq 0.10$, 0.05 and 0.01, respectively

3. Dormancy Management of Nursery Grown Woody Ornamentals

Objective:

To develop dormancy management strategies of field grown trees through the use of plant growth regulators and defoliants.

Background:

Growers try to accelerate the growth of trees and shrubs in order to have a saleable product in as short a time as possible. One problem resulting from "pushing" plants is that they fail to develop adequate dormancy levels in the fall leading to higher than acceptable rates of winter injury and loss (Thomas & Ahlers, 1999; Jalkanen er al., 1998).

Abscisic acid (ABA), a naturally occurring plant growth regulator (PGR), has been associated with the dormancy process. Until recently, field application of ABA has been prohibitively costly and so most ABA studies that have been published are typically lab or greenhouse studies (small scale). While a potential low cost source of ABA did exist (i.e. Toray Chemical Co., Japan), rendering field-scale studies economically feasible. Toray has now withdrawn their product from manufacture and therefore this chemical has been withdrawn from the trials. In some of the first trials, an ultra-pure (99%) crystaline lab grade ABA source (Sigma-Aldrich Chemical Co., USA) was used and prepared to the same concentration as the Toray ABA source. It too was discontinued in later trials.

Thidiazuron (TDZ) is a recently discovered plant growth regulator that has a number of interesting properties. Commercially it is marketed as Dropp (AgrEvo) and is labeled for use as a cotton defoliant. TDZ has been reported to increase dormancy in Malus species (Coleman and Estabrooks, 1992; Coleman *et al.*, 1992; Coleman and Estabrooks, 1988; Coleman and Estabrooks, 1985). Furthermore, exogenous application of TDZ has been shown to induce endogenous ABA synthesis, which may explain TDZ's role in dormancy induction (Wang and Faust, 1988; Thomas and Katterman, 1986; Wang and Faust, 1986). A sample of Dropp was been obtained for inclusion in our studies.

Ethylene is another naturally occurring PGR. Ethrel and Ethephon are two commercial preparations of ethylene (as 2-chloroethane phosphonic acid) already in use in the greenhouse, fruit & vegetable and nursery industries. In parts of the US, ethylene is applied in the fall as a defoliant. Studies indicate that timing and concentration are important considerations. While the onset of dormancy is not affected by ethylene application, fall application has been shown to delay spring bud-break by up to a week and to increase mid-winter hardiness levels (Crisosto et al., 1987; Raese, 1977; Proebsting and Mills, 1976; Proebsting and Mills, 1969). The main emphasis of this project is to accelerate growth; however, since spring frosts are unpredictable, a delay in the onset of growth in the spring would be advantageous in our region.

Greenhouse Trials

Overview:

Greenhouse trials will establish the effectiveness of PGR foliar application and test the assumption that high fertility conditions disrupt dormancy initiation. Vegetative maturity (VM) is the first important stage of dormancy. This is the stage where neither defoliation nor tip removal (i.e. removal of the apical meristem) will stimulate lateral bud break (Friesen & Stushnoff, 1989). A more quantitative definition was developed by Andrews (1996): VM occurs at the point at which an additional 10 days of acclimating conditions results in an increase of 5 days to budbreak. Red osier dogwood ecotypic clones (*Cornus sericea* L.) will be used in the greenhouse trials because the dormancy cycle varies widely among North American ecotypes of this species, has been studied extensively, and protocols for inducing and assessing VM have been well established and are used as standard dormancy assays in other species. In other words, much of the groundwork has already been established for studying dormancy management strategies under both controlled and field conditions. A further reason for using dogwoods for this portion of the study is that dogwoods pass through juvenility relatively quickly making them a good candidate for numerous and short term trials.

The ABA rate (10^{-4} M) was chosen because previous studies have indicated that this is an effective non-phytotoxic rate. The ethylene rate of 1000 ppm (0.1%) was chosen for a

similar reason. Dropp will be tested under greenhouse conditions using recommended levels for cotton (0.2 – 0.4 % a.i.) to test its effectiveness in inducing leaf drop and promoting dormancy induction as well as to evaluate plant phytotoxic response at these low rates.

General Experimental Design

The statistical design of all experiments will be Completely Randomized Design (CRD) unless otherwise indicated. In addition, all plants used in the individual experiments will be clonally propagated to reduce the plant-to-plant variation. In a typical greenhouse experiment, 120 to 250 plants are used depending on the number of treatments, replicates and ecotypes used. Plants can only be used one time; once vegetative maturity has been acquired, only a chilling period would induce new growth. Furthermore, we cannot be sure what effect treatments may have on subsequent growth (e.g. chilling requirement, date of budbreak, growth response, overall vigor, etc), necessitating using newly propagated and vigorously growing plants. In the first series of greenhouse experiments, both the UTAH (late dormant) and NWT (early dormant) dogwood clones were used to assess the effect of high fertility on dormancy and the effectiveness of ABA in overcoming the fertility effect. In subsequent trials, only the NWT clone was used because it responded to short-day dormancy induction treatment more rapidly.

There were seven greenhouse trials conducted. The first three trials had the following features in common: All plants were grown under long days (≥ 16 hours) with fertigation (400 ppm 20-20-20 + micronutrients) once a week until they began to flower at which time they were no longer considered juvenile. They were then grown under short day (9 hours) conditions and divided up into treatment groups. Fertilizer treatments (400 ppm 20-20-20 + micronutrients) began when short days were initiated and chemical treatments (e.g. ABA-Technical) began three weeks later. All chemical treatments including the water spray control were applied with a surfactant (0.10% Tween) to ensure even coverage and optimal uptake of chemical. Vegetative maturity (VM; a critical stage of dormancy before which plants will not cold acclimate) was assessed at 10-day intervals beginning after the first three weeks of short days and prior to the chemical treatments.

VM evaluation involves selecting one plant at random from each replicate, defoliating and removing the tip, and recording the number of days to bud break under long day conditions and once per week fertigation. There were three replicates per treatment with 12 plants per replicate. In the fourth and fifth trials, the fertilizer treatments were initiated under long days and continued for two weeks before short days conditions were imposed and continued until the end of the trial. Furthermore, PGR treatments were initiated after two weeks of short days and VM sampling occurred more often (5-day intervals instead of 10-day) than in the previous trials.

Ethylene was not evaluated under greenhouse conditions because it is already used in nurseries in the US and rate recommendations, effectiveness and cost/benefit analysis have already been established.

Trial 1

Objective:

To establish whether high fertility conditions delay dormancy acquisition as indicated by a delay in vegetative (VM) establishment.

Greenhouse Environment:

All plants were grown under short days (8 hr day/16 hr night). These conditions were imposed with black-out curtains opening at 8:00 AM and closing at 4:00 PM.

Treatments:

1) low fertility: weekly fertigation with 400 ppm 20-20-20+micronutrients (Lo-Fert)
2) high fertility: daily fertigation with 400 ppm 20-20-20+micronutrients (Hi-Fert)

Dogwood clones:

- NWT
- UTAH

Sampling occurred at ten-day intervals 3 weeks after treatments were initiated and days to bud-break were counted.

Results:

The 'UTAH' clone did not respond to short-day treatments (data not presented), whereas the 'NWT' clone responded well to both short-day and fertilizer treatments. Thirty-one (31) days after treatment (DAT), the 'NWT' Lo-Fert treatments had reached vegetative maturity (VM) and at 51 DAT, buds failed to break after more than 50 days. 'NWT' dogwoods in the Hi-Fert treatment reached VM by day 51 (by strict VM definition; see Trial Overview) but continued to break bud in subsequent defoliation (Table 5).

Table 5. Days to bud-break following defoliation and tip-removal of 'NWT' dogwood clone.

Defoliation date (DAT*)	*Hi-Fert*	*Lo-Fert*
21	9	9
31	11	14 (VM)
41	10	19
51	15 (VM ?)	no budbreak
66	17	no budbreak

*DAT = Days After Treatment

Discussion:

Previous work by others indicate that the 'UTAH' clonal selection is relatively insensitive to day-length and may not become vegetatively mature until 108 DAT under controlled environment conditions [cp. 'NWT' reaches VM 52 DAT under controlled environment condition] (Stevenson, 1994). Furthermore, there can be considerable winter die-back of the 'UTAH' clone under Saskatoon field conditions (personal observation) suggesting that this clone does not respond well to environmental queues and does not develop deep enough dormancy early enough to withstand early hard frosts in the fall. Based on these results, it was decided to eliminate the 'UTAH' clone from subsequent trials (Trial #2 was ongoing when this decision was reached and therefore does include 'UTAH').

The 'NWT' clone under low fertilizer conditions reached VM 31 DAT but under high fertilizer conditions did not reach VM a full 20 days later and continued to break bud after this period. The 'NWT' clone reaction to high fertility is more consistent with what has been reported anecdotally: lack of environmental synchronicity in the fall resulting in mild to severe winter die-back in otherwise hardy species and cultivars. Based on these results, the 'NWT' dogwood clone was used exclusively in future greenhouse trials (with the exception of Trial #2: see above paragraph).

Trial 2

Objective:

To determine whether exogenous application of ABA (10^{-4} M) reduces the delay in the onset of VM due to high fertility

Greenhouse Environment:

All plants were grown under short days (8 hr day/16 hr night). These conditions were imposed with black-out curtains opening at 8:00 AM and closing at 4:00 PM. Plants were grown under short-days for two weeks before ABA was applied. The first defoliation sampling occurred immediately before the ABA treatment and continued thereafter every 10 days.

Treatments:

1) low fertility: weekly fertigation with 400 ppm 20-20-20+micronutrients = Lo-Fert
2) high fertility: daily fertigation with 400 ppm 20-20-20+micronutrients = Hi-Fert
3) high fertility + ABA application: high fertility: daily fertigation with 400 ppm 20-20-20+micronutrients + a one time foliar application of ABA (10^{-4} M; Sigma Aldrich ultra pure lab grade) = ABA-Tech

Dogwood clone:

- UTAH

Results

The 'UTAH' did not reach VM as per definition (see discussion in Trial #1 and Trial Overview); however, bud-break was progressively delayed as short-day treatments continued in the low fertilizer treatment. A single application of ABA (ABA-Tech treatment) resulted an intermediate response to fertility and short-day conditions.

A single application of ABA reduced but does not overcome the delay in VM that high fertility causes (Figure 3). Eleven weeks after the single ABA application, high fertility plants reverted to active growth despite short day acclimating condition. This would indicate that high fertility conditions have a much stronger influence on dormancy than previously thought. It has been assumed in the past that once plants began to go dormant, that this process was difficult to reverse particularly if the plants were responding to environmental queues such as short days.

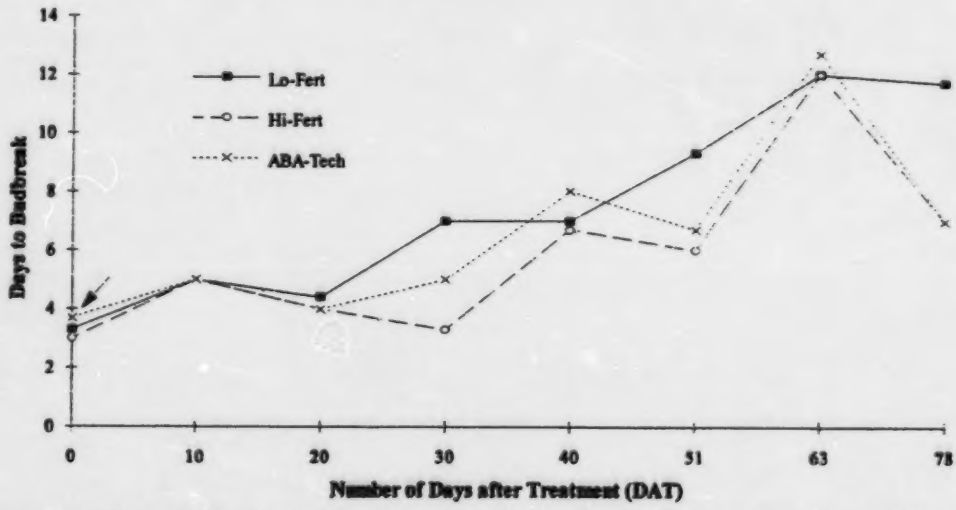

Figure 3. ABA application reduces the delay in the onset of vegetative that is due to high fertility condition maturity in UTAH dogwood clones (arrow indicates ABA application date)

Trial 3

Objectives

1) To evaluate the effect of multiple applications of ABA on overcoming the delay in VM attainment caused by high fertility
2) To compare two sources of ABA for effectiveness and ease of preparation

Materials & Methods

Greenhouse Environment:

All plants were grown under short days (8 hr day/16 hr night). These conditions were imposed with black-out curtains opening at 8:00 AM and closing at 4:00 PM. One of the sources of ABA is a commercial preparation from Toray Industries (Japan). Toray-ABA is a natural form of ABA than technical grade (Sigma).

Treatments:

1) low fertility: weekly fertigation with 400 ppm 20-20-20+micronutrients = Lo-Fert
2) high fertility: daily fertigation with 400 ppm 20-20-20+micronutrients = Hi-Fert
3) high fertility + ABA (technical): daily fertigation with 400 ppm 20-20-20+micronutrients + three foliar applications of ABA (10^{-4} M; Sigma technical lab grade) at 8 day intervals = ABA-Tech
4) high fertility + ABA (Toray 15% solution): daily fertigation with 400 ppm 20-20-20+micronutrients + three foliar applications of ABA (10^{-4} M; Toray 15% solution) at 8 day intervals = ABA-Toray

Dogwood clone: Northwest Territories (NWT) ecotype

Results

The NWT clone is very sensitive to short days and was not responsive to high fertility conditions (Fig. 4). This was not entirely expected in view of the results from Trial #1. It is possible that since the short day conditions began at the same time as the high fertility treatments, plants were more likely to respond to the short days than the high fertility treatment. A refinement to subsequent trials initiated high fertility treatments

under long days, ensuring that plants were 'loaded up' with nitrogen before short days are initiated to simulate typical nursery management practices.

In this trial, the two ABA sources had similar effects. Since the Toray source is much easier to work with (e.g. just dilute in water vs. dissolve in small amount of strong alkaline solution, dilute in water and reduce pH to 6.0 from approx. 8.5 with strong acid), the use of ABA technical will be discontinued in future trials.

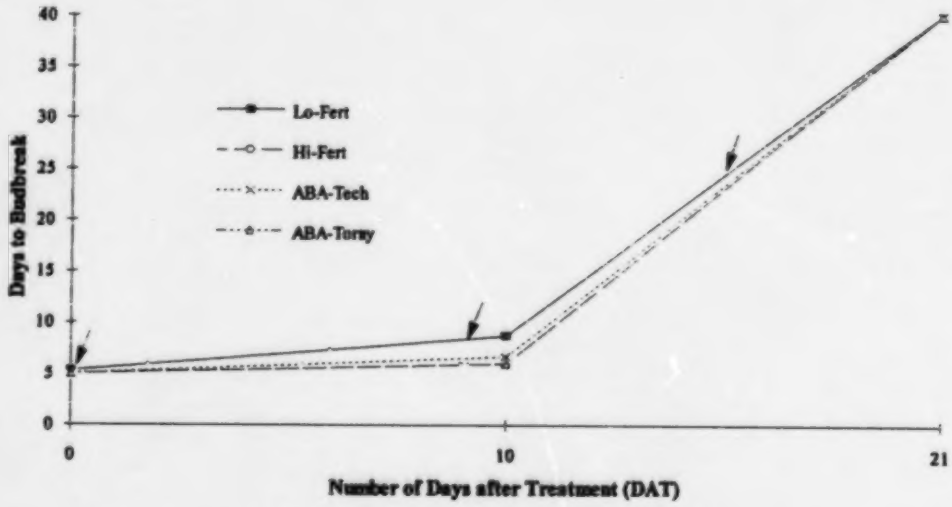

Figure 4. ABA application shows little effect on VM in NWT dogwood clones as this clone is highly responsive to day length in terms of VM acquisition (arrows indicates ABA application dates)

Trial 4

Objective

To evaluate the effectiveness of the defoliant Dropp 50WP (AgrEvo; thidiazuron = TDZ) in inducing VM in plants grown under high fertility

Materials & Methods

Greenhouse Environment:

All plants were grown under short days (8 hr day/16 hr night). These conditions were imposed with black-out curtains opening at 8:00 AM and closing at 4:00 PM. Treatments included one low-fertility (control) and three high-fertility treatments. The following modifications were made to pre-treatment conditions:

1) Plants were grown under the appropriate fertilizer treatment regimes (i.e. low fertility or high fertility) under long days for three weeks before exposing them to short days. This was to ensure that plants grown under high fertility conditions were growing vigorously before exposure to dormancy inducing conditions.
2) ABA and Dropp were applied 10 and 15 days after exposure to short days (day 0 = 0 DAT, counted from the time of first PGR treatment application)
3) VM sampling occurred at 5-day intervals instead of 10-day intervals to gain a more accurate view of the change in VM status. Sampling began immediately before the first ABA and Dropp treatments.

Treatments:

1) low fertility: weekly fertigation with 400 ppm 20-20-20+micronutrients = Control
2) high fertility: daily fertigation with 400 ppm 20-20-20+micronutrients = High Fertilizer
3) high fertility + ABA (Toray 15% solution): daily fertigation with 400 ppm 20-20-20+micronutrients + two foliar applications of ABA (10^{-4} M; Toray 15% solution) = ABA-Toray (0 DAT and 5 DAT)
4) high fertility + Dropp (AgrEvo 50WP): daily fertigation with 400 ppm 20-20-20+micronutrients + two applications of Dropp 50WP (0.2% a.i. w/w)= Dropp (0 DAT and 5 DAT)

Treatments 1 and 2 were sprayed with water + surfactant at the same time as PGR treatments (0 DAT and 5 DAT)

Dogwood clone: Northwest Territories (NWT) ecotype

Statistical Analysis

Days to bud-break (DBB) data was tested with ANOVA and means were separated using LSD (Fisher's protected) whenever $p \leq 0.05$.

Results

Only Control (Treatment 1) acquired VM (between 15 and 20 DAT). The high fertility conditions in the other three treatments disrupted dormancy acquisition so successfully that VM acquisition did not occur by the end of the experiment (35 DAT). At 15 DAT, DBB in control was significantly ($p \leq 0.01$) different than High Fertilizer and ABA-Toray (Treatments 2 and 3) and was equivalent to Dropp (Treatment 4). At 20 DAT and to the end of the trial, Control acquired VM and DBB was significantly ($p \leq 0.01$) different than all other treatments. The data was then re-analyzed by disregarding Control data. In this analysis, DBB in the Dropp treatment was significantly different from ABA-Toray and High Fertilizer treatments at 15 and 20 DAT ($p \leq 0.05$ and 0.10, respectively; also DBB in the Dropp treatment was significantly [$p \leq 0.05$] different from ABA-Toray at 20 DAT) and equivalent on all other dates (Table 6; Figure 5).

Even though Dropp treatment failed to overcome the fertility effect, there were a number of observations, aside from DBB differences, which suggested that Dropp had an effect on dormancy acquisition: 1) leaves were turgid but droopy (7 DAT); 2) leaves were easily detached compared to the other treatments (14 DAT); 3) slight stem reddening (14 DAT); and 4) there were white root tips visible at the container soil interface of Toray and High Fertilizer treatments but none present in Control or Dropp treatments (20 DAT) (Figure 6).

Undesirable side effects in the 0.1% TDZ treatment included nodal swelling, leaf deformities and bud necrosis (Figure 7). The nodal swelling indicate that not only is leaf abscission zone formation stimulated but also other growth processes. Nodes were not sectioned to determine the nature of growth in the nodes, but since this area is meristimatic, it was thought that the growth is due to both cell division and enlargement.

Bud necrosis and leaf deformities suggest that multiple applications of TDZ at 0.1% are phytotoxic.

M121

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Table 6. Days to bud-break (DBB) in dogwood 'NWT' (*Cornus sericea* 'NWT') over time following plant growth regulator (PGR) treatments

Treatment	Days to Bud-Break (DBB)							
	0 DAT	5 DAT	10 DAT	15 DAT	20 DAT	26 DAT	30 DAT	35 DAT
Control	6.25	7.75	8.50	8.00	56.00	79.00	79.23	100.00
High Fertilizer	4.75	5.25	6.50	4.75	6.75	9.50	9.50	11.00
ABA-Toray	4.00	5.00	7.25	5.25	6.25	8.50	8.00	11.00
Dropp	4.75	6.75	8.50	8.75	11.00	7.50	7.25	10.25
Statistical Analysis[‡]								
Signif. (#1)[†]	ns	ns	ns	*	*	**	**	**
LSD	-	-	-	2.75	39.30	46.06	45.26	5.88
CV %	26.3	28.1	22.5	26.7	127.7	81.6	80.6	8.2
Signif. (#2)[†]	ns	ns	ns	*	*,+	ns	ns	ns
LSD	-	-	-	2.40	4.69, 3.80	-	-	-
CV %	36.3	21.6	26.5	24.0	36.7	50.0	40.3	29.2

[‡]Analysis #1 included Control data, #2 excluded Control data

[†]ns; +, * and ** = not significant; significant at $p \leq 0.10$, 0.05 and 0.01, respectively

Table 6. Days to bud-break (DBB) in dogwood 'NWT' (*Cornus sericea* 'NWT') over time following plant growth regulator (PGR) treatments

Treatment	Days to Bud-Break (DBB)							
	0 DAT	5 DAT	10 DAT	15 DAT	20 DAT	26 DAT	30 DAT	35 DAT
Control	6.25	7.75	8.50	8.00	56.00	79.00	79.23	100.00
High Fertilizer	4.75	5.25	6.50	4.75	6.75	9.50	9.50	11.00
ABA-Toray	4.00	5.00	7.25	5.25	6.25	8.50	8.00	11.00
Dropp	4.75	6.75	8.50	8.75	11.00	7.50	7.25	10.25
Statistical Analysis‡								
Signif. (#1)†	ns	ns	ns	*	*	**	**	**
LSD	-	-	-	2.75	39.30	46.06	45.26	5.88
CV %	26.3	28.1	22.5	26.7	127.7	81.6	80.6	8.2
Signif. (#2)†	ns	ns	ns	*	*,+	ns	ns	ns
LSD	-	-	-	2.40	4.69, 3.80	-	-	-
CV %	36.3	21.6	26.5	24.0	36.7	50.0	40.3	29.2

‡Analysis #1 included Control data, #2 excluded Control data

†ns; +, * and ** = not significant; significant at $p \leq 0.10$, 0.05 and 0.01, respectively

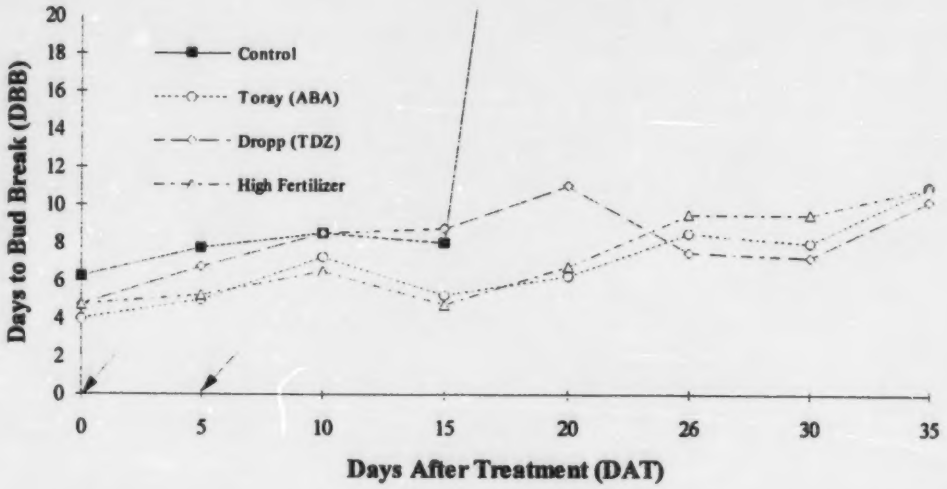

Figure 5. Days to budbreak over time following application of ABA and TDZ. Arrows indicate application data.

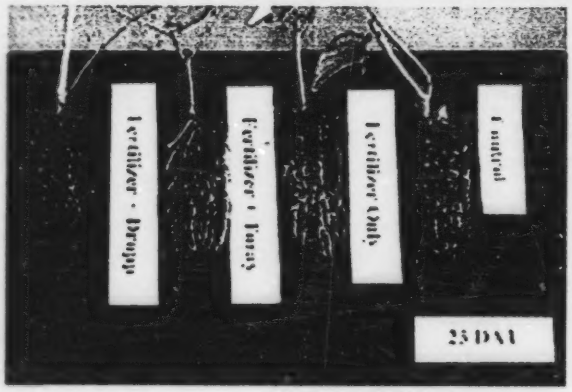

Figure 6. Treatment effect (High fertility, High Fertility in combination with ABA or TDZ and control) on root growth under greenhouse conditions.

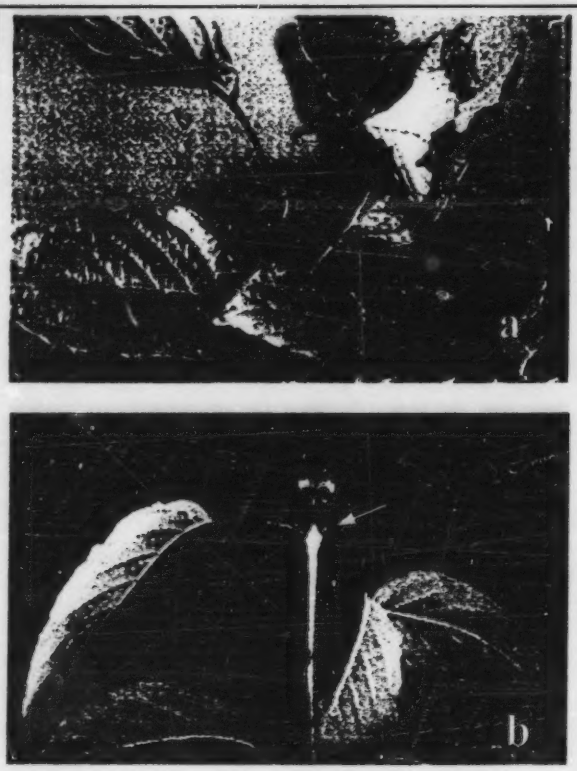

Figure 7. Dogwood leaf node characteristics after 37 days of short day exposure. a) Control (normal). b) 23 days after 2 applications of 0.1% TDZ. Arrow in 'b' indicates swollen node and reflexed leaves. Topmost node in 'b' is exhibiting leaf deformation

Trial #5: Lower Dropp rates + multiple applications:

Materials & Methods

Pretreatment conditions:

Plants were grown under the appropriate fertilizer treatment regimes (i.e. low fertility [LF] or high fertility [HF]) under long days (16 hours) for three weeks before exposure to short days. This was to ensure that plants grown under high fertility conditions were growing vigorously before exposure to dormancy inducing conditions. Plants were grown for an additional two weeks under short days (9 hours) before Dropp treatments were initiated.

Treatments:

1) Control-LF (fertilized once/week with 400 ppm 20-20-20+micronutrients)
2) Control-HF (fertilized daily with 400 ppm 20-20-20+micronutrients)
3) Dropp 0.05% (fertilized daily with 400 ppm 20-20-20+micronutrients)
4) Dropp 0.10% (fertilized daily with 400 ppm 20-20-20+micronutrietnts)

Dropp treatments (treatments 3 and 4) were applied four times at five-day intervals beginning 14 days after short days were initiated. Control-HF (treatment 2) was sprayed with water + surfactant at the same time as Dropp treatments. All treatment solutions (incl. Control) were prepared with reverse osmosis water and supplemented with 0.10% Tween 20. Vegetative maturity (VM) was assessed 10 times commencing immediately before Dropp treatments and subsequently at five day intervals. There were six replicates with one plant per replicate for each sampling time. The trial was arranged in Completely Randomized Block Design (4 treatments x 10 sampling periods x 6 replicates x 1 plant/treatment/sampling period/replicate = 240 plants).

Dogwood clone: Northwest Territories (NWT) ecotype

Statistical Analysis

Regression analysis and advanced curve fitting routines (TableCurve 2D, SPSS Inc.) were used to test treatment response. Andrews' (1996) definition of vegetative maturity (the point at which an additional 10 days of natural dormancy-inducing condition results in a delay of 5 days to budbreak) was used to determine the date of VM for each treatment. This was accomplished by taking the first derivative of the regression equation, setting it equal to 0.5 and solving for x (i.e. y' = 0.5, solve for x).

Results

Depending on treatment, two different regression curves developed from the data. Curve Type I ($y = a + bx^{2.5}$) best described treatments 1 and 4 (Control-LF and Dropp 0.10%, respectively) where there was little delay in plant response to short days (i.e. rapid advancement towards vegetative maturity (VM). Curve Type II ($y = a + be^{cx}$) best

described treatments 2 and 3 (Control-HF and 0.05% Dropp, respectively) where there was a long delay in plant response to short days (Figures 8 - 11).

Treatment #3 (0.05% Dropp) overcame some the high fertility affect by reducing VM acquisition by approx. 6 days but was still 11 days behind Control-LF. Treatment #4 (0.10% Dropp) completely overcame the high fertility affect and in fact accelerated VM acquisition by approx. 3.5 days.

Visual observations that suggested Dropp treatments affected hardening processes were 1) leaves were turgid but droopy (7 DAT); 2) leaves were easily detached compared to the other treatments (14 DAT); 3) slight stem reddening (14 DAT); and 4) there were white root tips visible at the container soil interface of Toray and High Fertilizer treatments but none present in Control or Dropp treatments (18 DAT). These latter responses were identical to Trial #4. Also as in Trial #4, there was nodal swelling and some bud necrosis in the higher Dropp rate (0.10% a.i.).

Discussion

Two basic assumptions were tested in the first five trials: high fertility disrupts normal dormancy processes and dormancy processes cannot be reversed once initiated.

Trial #1 established very clearly that high fertility delayed the onset of vegetative maturity in a relative environmentally sensitive clone by as much as 20 days. The second experiment established that exogenous ABA was able to reduce the effect that high fertility conditions had on VM. With continued high fertility, it appeared that the VM was delayed or prevented from occurring, thus challenging our second assumption. The clone used in Trial #2 is relatively insensitive to changes in day-length; according to Stevenson (1994), UTAH does not acquire VM until after 108 days of exposure to short days under controlled environmental conditions. Our trial lasted only 78 days. VM may not have been initiated in the UTAH clone and therefore our basic assumption that dormancy processes are irreversible after VM has been achieved still holds true. Since the UTAH requires a long dormancy initiation period, it was decided to remove this clone

from future trials and use the NWT clone, whose dormancy characteristics are closer matched to the hardy plant species grown on the prairies.

Dropp (thidiazuron (TDZ), AgrEvo), a commonly used plant-growth-regulator (PGR) in cotton was evaluated in Trials #4 and 5. The data indicates that Dropp does influence dormancy and is able to overcome the effects of high fertility conditions by multiple application. The significance of droopy, turgid and easily detached leaves suggests that abscission layers developed in Dropp treated plants, a phenomenon normally associated with plant preparation for winter as is the stem reddening that was observed (Smithberg & Weiser, 1968). Further, the lack of white root tips in the Dropp treatment suggests that growth halted in a similar manner to Control (naturally induction). The only negative response to Dropp application continues to be the development of swollen and unsightly nodes and some bud necrosis.

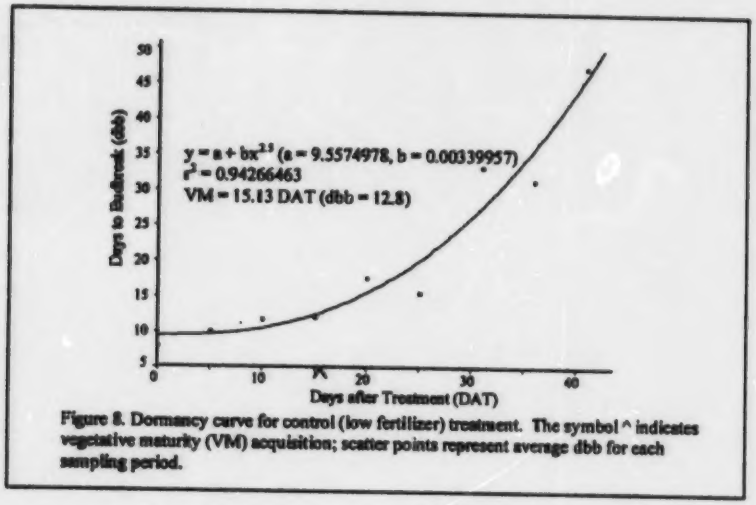

Figure 8. Dormancy curve for control (low fertilizer) treatment. The symbol ^ indicates vegetative maturity (VM) acquisition; scatter points represent average dbb for each sampling period.

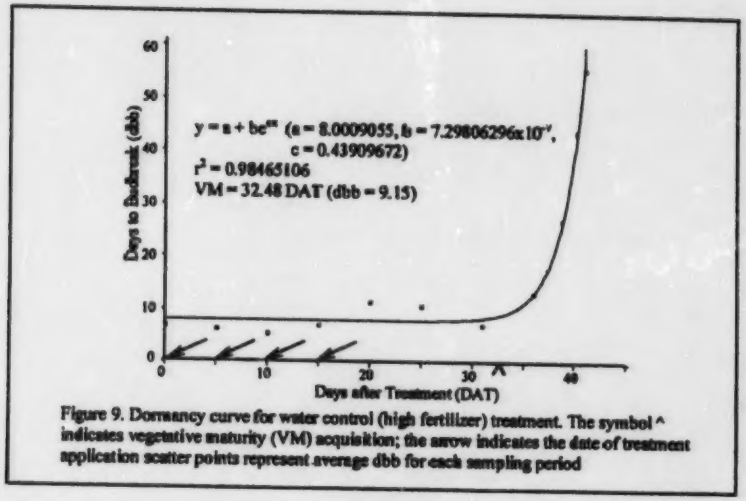
y = a + be^cx (a = 8.0009055, b = 7.29806296x10⁻⁷, c = 0.43909672)
r² = 0.98465106
VM = 32.48 DAT (dbb = 9.15)
Days to Budbreak (dbb)
Days after Treatment (DAT)

Figure 9. Dormancy curve for water control (high fertilizer) treatment. The symbol ^ indicates vegetative maturity (VM) acquisition; the arrow indicates the date of treatment application scatter points represent average dbb for each sampling period

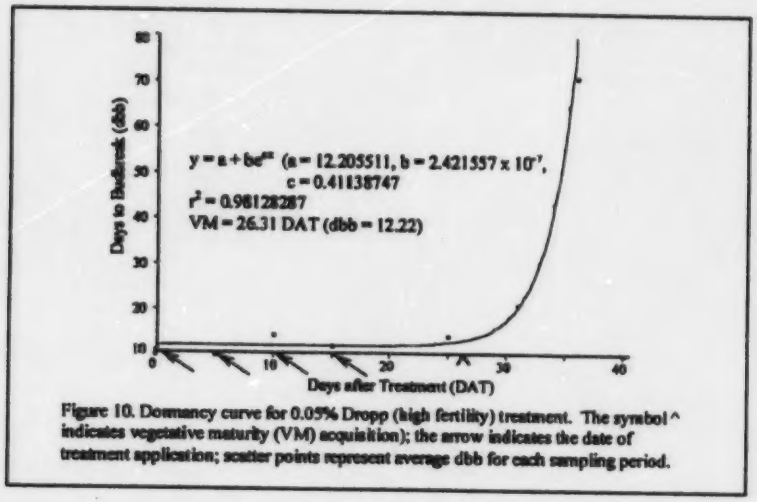
y = a + be^cx (a = 12.205511, b = 2.421557 x 10⁻⁷, c = 0.41138747)
r² = 0.98128287
VM = 26.31 DAT (dbb = 12.22)
Days to Budbreak (dbb)
Days after Treatment (DAT)

Figure 10. Dormancy curve for 0.05% Dropp (high fertility) treatment. The symbol ^ indicates vegetative maturity (VM) acquisition); the arrow indicates the date of treatment application; scatter points represent average dbb for each sampling period.

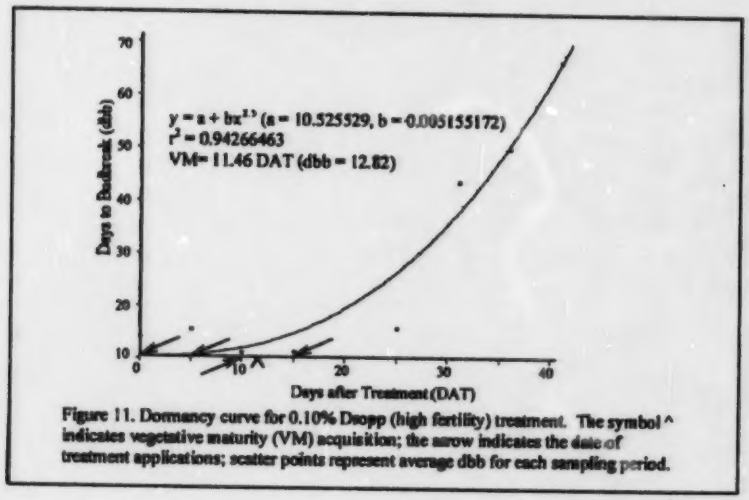

Figure 11. Dormancy curve for 0.10% Dropp (high fertility) treatment. The symbol ^ indicates vegetative maturity (VM) acquisition; the arrow indicates the date of treatment applications; scatter points represent average dbb for each sampling period.

Trial #6: Reduced Frequency and Concentration of Dropp (TDZ) Application

Multiple applications of Dropp reduced the fertility effect on dormancy in previous greenhouse experiments, but undesirable side effects such as enlarged nodes and lateral bud necrosis developed. This trial evaluated the effect of three applications of low concentration (0.05%) TDZ on reducing the effect of high fertility on dormancy and avoiding the negative side effects.

Materials & Methods

Pretreatment conditions:

Plants were grown under the appropriate fertilizer treatment regimes (i.e. low fertility [LF] or high fertility [HF]) under long days (16 hours) for three weeks before exposing them to short days. This was to ensure that plants grown under high fertility conditions were vigorously growing before they are exposed to dormancy inducing conditions. Plants were grown for an additional two weeks under short days (9 hours) before TDZ treatments were initiated.

Treatments:

1) Control-LF (fertilized once/week with 400 ppm 20-20-20+micronutrients)
2) Control-HF (fertilized daily with 400 ppm 20-20-20+micronutrients)
3) Dropp (0.05% ai) (fertilized daily with 400 ppm 20-20-20+micronutrietnts)

The Dropp treatment (treatment 3) was applied three times at five-day intervals beginning 14 days after short days were initiated. Controls (treatments 1 & 2) were sprayed with water + surfactant at the same time as Dropp treatments. All treatment solutions (incl. Control) were prepared with reverse osmosis water and supplemented with 0.10% Tween 20. Vegetative maturity (VM) was assessed 9 times: immediately before Dropp application and then 24 hours later for each of the three applications, followed by assessment every five days until the end of the trial. There were six replicates with one plant per replicate for each sampling time. The trial was arranged in Completely Randomized Block Design (4 treatments x 10 sampling periods x 6 replicates x 1 plant/treatment/sampling period/replicate = 240 plants).

Dogwood clone: Northwest Territories (NWT) ecotype

Statistical Analysis

Regression analysis and advanced curve fitting routines (TableCurve 2D, SPSS Inc.) were used to test treatment response. Andrews' (1996) definition of vegetative maturity (the point at which an additional 10 days of natural dormancy-inducing condition results in a delay of 5 days to budbreak) was used to determine the date of VM for each treatment. This was accomplished by taking the first derivative of the regression equation, setting it equal to 0.5 and solving for x (i.e. y' = 0.5, solve for x).

Results

The low fertilizer control treatment achieved VM at 10.7 days after the beginning of the TDZ treatments or nearly 25 days after short days were initiated. The high fertilizer control treatment achieved VM a full 7 days later demonstrating that high fertility does indeed have an affect on dormancy development and acquisition. The dormancy curve for the TDZ treatment was bell curved. If only the front of the curve is considered (i.e. from 1 – 23 DAT), VM appears to occur 2.4 days after treatments initiated. Days to budbreak (DBB) continue to increase dramatically as long as TDZ applications continue. Once TDZ is discontinued, DBB fell off equally dramatically to pre-application levels and held steady at that level for the duration of the trial (Figures 12 – 14b).

Leaves on plants treated with TDZ were reflexed but not wilting within 10 days of application; these leaves were easily detached. No other treatments developed easily detached and reflexed leaves. Plants in the low fertility Control group developed red stems 11 DAT (coinciding with VM assessment). The other treatments developed red stems by 18 DAT (coinciding with VM assessment for high fertility control) at which time Control-LF had the reddest stems (visual assessment only). No distorted nodes were present nor did any of the lateral buds appear to be dead on the TDZ treatments.

Discussion

As demonstrated previously, VM acquisition was delayed with high fertility conditions. With lower TDZ rates and fewer applications, the negative effects (nodal swelling and lateral bud necrosis) was eliminated. Furthermore, TDZ had the desired affect of advancing VM, but only as long as TDZ continued to be applied. Once TDZ application was discontinued, the effect was reversed and growth was stimulated even though the conditions satisfying VM definition were previously satisfied (i.e. the point at which an additional 10 days of acclimating conditions results in an increase of 5 days to budbreak).

A review of some recent work provides some clues why TDZ may have had this effect. TDZ is a synthetic plant growth regulator (PGR) that is cytokinin-like in activity and chemistry (structure and makeup) (Mok et al., 1982). In addition to the cytokinin effects, biosynthesis of auxin, abscisic acid, ethylene, RNA and protein is also stimulated (Hutchinson et al., 1996; Hare & Van Staden, 1994; Visser et al., 1992; Wan et al., 1986). Also, TDZ effects are species dependent (Zybkova et al., 1983). Dormancy is a process that is initiated by external events but physiological changes are controlled or mediated with changes in amounts all PGR's relative to one another rather than the absolute increase or decrease of individual PGR's (Wareing & Saunders, 1971). It is likely that the stimulatory effect that TDZ has on many of the endogenous PGR levels in conjunction with high fertility conditions upset the PGR balance necessary for dormancy initiation and maintenance so that growth rather than growth cessation was ultimately signaled.

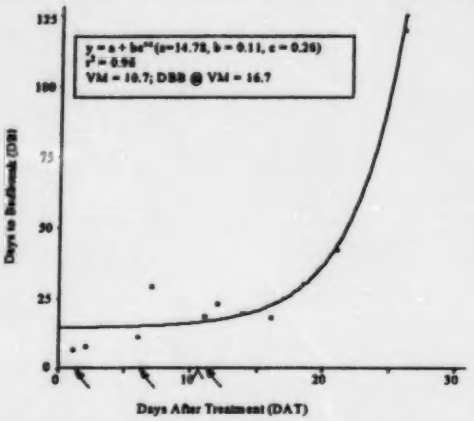

Figure 12. Dormancy curve for control (low fertilizer) treatment. The symbol ^ indicates vegetative maturity (VM) acquisition; scatter points represent average dbb for each sampling period; arrows indicate date of treatments

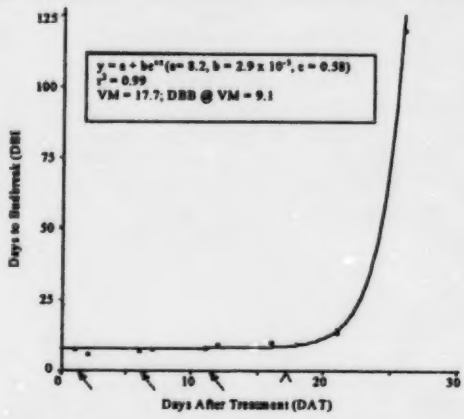

Figure 13. Dormancy curve for control (high fertilizer) treatment. The symbol ^ indicates vegetative maturity (VM) acquisition; scatter points represent average dbb for each sampling period; arrows indicate date of treatments

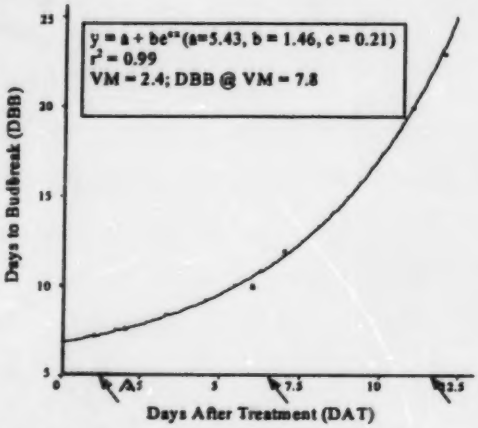

Figure 14a. Dormancy curve for Dropp (high fertilizer) treatment. The symbol ^ indicates vegetative maturity (VM) acquisition; scatter points represent average dbb for each sampling period; arrows indicate date of treatments

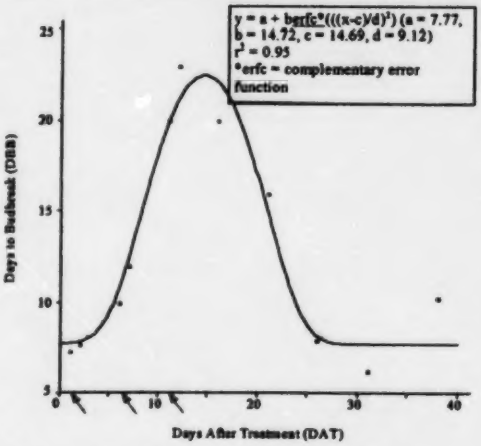
y = a + berfc*(((x-c)/d)²) (a = 7.77,
b = 14.72, c = 14.69, d = 9.12)
r² = 0.95
*erfc = complementary error function
Days to Budbreak (DBB)
Days After Treatment (DAT)

Figure 14b. Dormancy curve for Dropp (high fertilizer) treatment. Scatter points represent average dbb for each sampling period; arrows indicate date of treatments

Trial #7 Reduced frequency of Dropp application with and without high fertility conditions:

Multiple applications of Dropp did reduce the fertility affect on dormancy in previous greenhouse experiments, but undesirable side effects such as enlarged nodes and lateral bud necrosis. In Trial #6, reduced frequency and concentration initially induced VM but ultimately stimulated growth. This trial evaluated the effect of even further reduced frequency of TDZ application in the presence of both high and low fertility conditions to determine what role fertility has on the stimulatory effect of TDZ.

Materials & Methods

Pretreatment conditions:

Plants were grown under the appropriate fertilizer treatment regimes (i.e. low fertility [LF] or high fertility [HF]) under long days (16 hours) for three weeks before exposing them to short days. This was to ensure that plants grown under high fertility conditions were vigorously growing before they are exposed to dormancy inducing conditions. Plants were grown for an additional two weeks under short days (10 hours) before TDZ treatments were initiated. The short day photoperiod was extended by 1 hour because VM was being induced very quickly in the control treatment in previous trials. The one hour extension would slow down VM acquisition as well to better simulate late fall light conditions (as opposed to early winter light conditions).

Treatments:

1) Control-LF (fertilized once/week with 400 ppm 20-20-20+micronutrients)
2) Control-HF (fertilized daily with 400 ppm 20-20-20+micronutrients)
3) Dropp (0.05% ai)-LF (fertilized once/week with 400 ppm 20-20-20+micronutrients)
4) Dropp (0.05% ai)-HF (fertilized daily with 400 ppm 20-20-20+micronutrietnts)

The Dropp treatments (treatments 3 & 4) were applied two times at five-day intervals beginning 14 days after short days were initiated. Controls (treatments 1 & 2) were

sprayed with water + surfactant at the same time as Dropp treatments. All treatment solutions (incl. Control) were prepared with reverse osmosis water and supplemented with 0.10% Tween 20. Vegetative maturity (VM) was assessed 9 times: immediately before Dropp application and then 24 hours later for each of the three applications, followed by assessment every five days until the end of the trial. There were six replicates with one plant per replicate for each sampling time. The trial was arranged in Completely Randomized Block Design (4 treatments x 10 sampling periods x 6 replicates x 1 plant/treatment/sampling period/replicate = 240 plants).

Dogwood clone: Northwest Territories (NWT) ecotype

Statistical Analysis

Regression analysis and advanced curve fitting routines (TableCurve 2D, SPSS Inc.) were used to test treatment response. Andrews' (1996) definition of vegetative maturity (the point at which an additional 10 days of natural dormancy-inducing condition results in a delay of 5 days to budbreak) was used to determine the date of VM for each treatment. This was accomplished by taking the first derivative of the regression equation, setting it equal to 0.5 and solving for x (i.e. $y' = 0.5$, solve for x).

Results

VM acquisition was pushed back compared to Trial #6 as expected with the longer (10 hr) photoperiod. VM occurred 31.9 days after treatment initiation in treatment 1 (Control-LF). Plants in the high fertility control treatment (Control-HF) did not achieve VM. VM was advanced in treatment 3 (Dropp-LF) by 9 days over that of treatment 1 (Control-LF). As in the previous trial (Trial #6), high fertility conditions + Dropp application (Dropp-HF) initially resulted in a dramatic increase in DBB; after Dropp applications ceased, DBB fluctuated, reaching at one point pre-application levels (Figures 15 – 18).

There were none of the negative physical effects (i.e. swollen nodes or bud necrosis) associated with Dropp + Low Fertility application and stem reddening occurred in treatments 1, 2 and 3.

Discussion

High fertility again delayed/prevented VM acquisition as seen in previous trials. Without the high fertility stimulus, TDZ is able to advance or induce earlier VM acquisistion by several days over that of control. Hardiness (timing?) levels increase with the age of a plant (Hubackova, 1994; Shadrina, 1980; Chen & Li, 1978; Reif, 1978; Ryadnova et al., 1974), therefore this treatment has some promise in protecting young nursery grown trees until they are old enough to withstand Saskatchewan winters.

The high fertilizer levels in conjunction with TDZ produced somewhat erratic results. Fertilizer is a confounding effect that can overcome environmental signaling despite artificially modifying endogenous PGR levels. TDZ mode of action is not well understood and many processes are initiated or inhibited depending on the plant's state, species, and environment. PGR/s do not work independently of one another but in concert and relative to a plant's current physiological state and environment. TDZ is not able to overcome the high fertility effect on dormancy without repeated application at a relatively high concentration. This practice can have a number of undesirable side effects including nodal swelling, bud necrosis and leaf deformation.

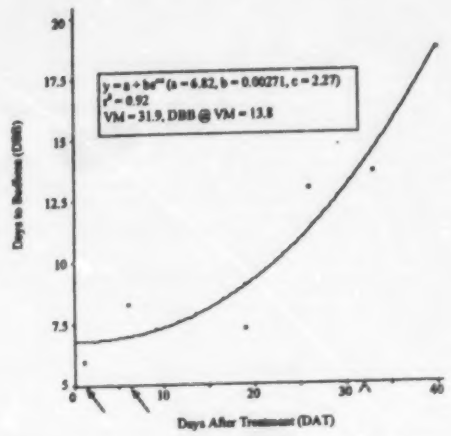

Figure 15. Dormancy curve for control (low fertilizer) treatment. The symbol ^ indicates vegetative maturity (VM) acquisition; scatter points represent average dbb for each sampling period; arrows indicate date of treatments

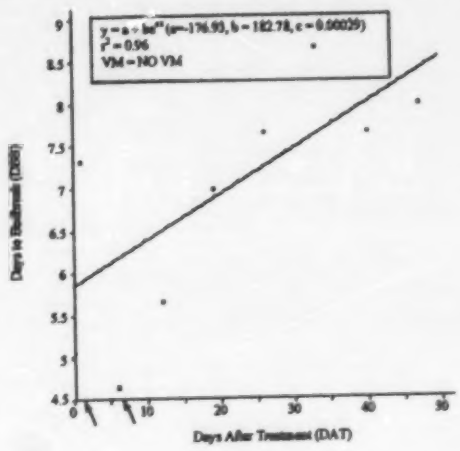

Figure 16. Dormancy curve for control (high fertilizer) treatment. Scatter points represent average dbb for each sampling period; arrows indicate date of treatments

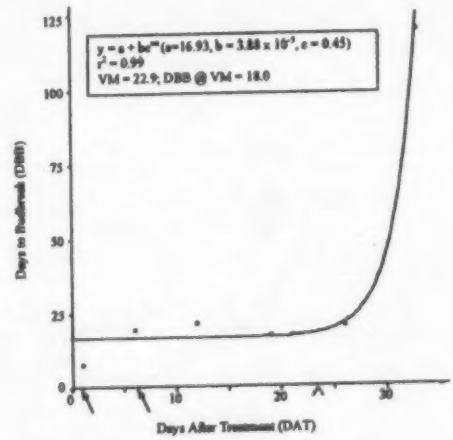

Figure 17. Dormancy curve for Dropp (low fertiiizer) treatment. The symbol ^ indicates vegetative maturity(VM) acquisition; scatter points represent average dbb for each sampling period; arrows indicate date of treatments.

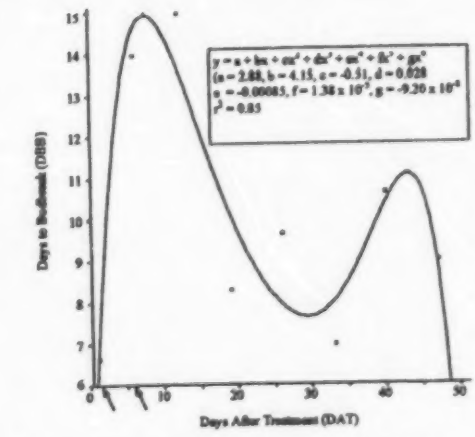
y = a + bx + cx² + dx³ + ex⁴ + fx⁵ + gx⁶
(a = 2.88, b = 4.15, c = -0.51, d = 0.028
e = -0.00085, f = 1.38 x 10⁻⁵, g = -9.20 x 10⁻⁸
r² = 0.85
Days to Budbreak (DBB)
Days After Treatment (DAT)

Figure 18. Dormancy curve for Dropp (high fertilizer) treatment. Scatter points represent average dbb for each sampling period; arrows indicate date of treatments

***Field trials* (3. Dormancy Management, cont'd)**

Overview:

Field trials began in the fall of 1999 on amur maples (*Acer ginnala* Maxim.) planted in the previous summer. Amur maple was chosen for the field 7trials because they are prone to nutrient deficiencies when grown in alkaline soil making them an excellent candidate for accelerated growth strategies. One hundred forty-four (144) clonally propagated amur maples (*Acer ginnala;* six-month rooted cuttings) were established in the field (U of S Horticulture research plots) in August 1998 under drip irrigation and black plastic mulch. This group of maples was divided into three subgroups for three separate trials: 1) foliar feeding throughout the season, 2) fall foliar feeding and 3) dormancy management (see section 1. Foliar Feeding for trials with amur maple subgroups 1 & 2). All maples were fertilized via drip irrigation with 84 kg nitrogen/ha (75 lb. nitrogen/acre) from 20-20-20 + micronutrients two times during the growing season (May 28 and August 3, 1999).

Materials & Methods:

Treatments were based on greenhouse results (see Greenhouse Trials #4 and #5). While 0.1% TDZ was the most effective treatment in Greenhouse Trial #5, there were some growth abnormalities. It was decided therefore to use the less damaging (but also less effective) 0.05% TDZ rate applied two times, 5 days apart.

Treatments:

1. Control (water applied on Sept. 10, 1999)
2. Dropp (0.05% TDZ applied on Sept. 10 and Sept. 15, 1999)
3. Ethrel (0.1% ai, applied on Sept. 10, 1999)

Plants were grown under high fertility conditions supplemented with foliar applied 2% nitrogen (as urea) throughout the growing season. (The first foliar urea application occurred on June 16, 1999 when the first set of leaves was fully expanded. Due to weather, further applications were not possible until July 8, 1999, after which time treatments were applied weekly until August 27, 1999 [nine foliar applications in total]).

Caliper measurements were taken on May 26 and again on October 15, 1999. Date of 50% and 100% leaf drop was recorded following treatment. In the spring (2000), date of bud break, percent winterkill and caliper were recorded.

Statistical Analysis

Treatments were arranged in Complete Randomized Block Design with 5 replicates x 3 trees/treatment/replicate. Data will be tested with ANOVA and treatment means will be compared using LSD (Fisher's protected).

Results

Date of 50% (October 15) and 100% (October 29) leaf drop were not affected by treatment (data not shown). Neither Dropp nor Ethrel treatments significantly affected caliper development or fresh weight. All treatments were significantly ($p \leq 0.05$) different from one another with respect to winterkill, with the Dropp treatment sustaining the most damage, followed by Etherel and then control treatments.

Discussion

These results were not as expected based on the majority of literature reports describing TDZ & woody ornamental field experiments. However in light of the results of the last two greenhouse experiments, some sense can be made from the winterkill results. The TDZ treated plants were the least prepared for winter. It is possible that the high fertility conditions greatly influenced the TDZ treatments in the same manner as the dogwoods in greenhouse trials 6 and 7 and VM acquisition was greatly delayed or even prevented. The question that arises is: why was the control group, which was also subject to high fertility conditions not as damaged by low temperature? Again the results from greenhouse trial 7 suggest an answer. The high fertility treatment did eventually reach VM and, presumable, subsequent hardening. The high fertility treatment + TDZ did not reach VM at all and therefore would have been unable to develop any degree of hardiness. This is possibly what occurred in the field, where the control treatment eventually attained VM and subsequent hardening (therefore survived butter than the

Dropp treatment). The Dropp treatment may have initially positively affected as in the greenhouse trials, but obviously was not able to develop sufficient hardiness levels.

The Ethrel treatment also resulted in significant winterkill levels. This response was not expected as reports in literature have not made mention on its affect on dormancy or hardiness. Crisosto et al. (1989) reported that ABA and ethylene levels were elevated during the winter in peach (Prunus persica 'Red Haven') following a late fall (10% leaf drop) Ethrel application. A later study (Crisosto et al., 1990) reported that an earlier fall Ethrel application (i.e. before leaf drop and 15 days before VM), resulted in reduced flower number per node, fruit set and yield of peach (P. persica 'Red Haven') the following spring. The high winter kill level in the control treatment suggests that VM was at best delayed to after treatments were initiated. [VM determination was not performed because of its destructive nature and limited size of the treated plants.] It is likely that Ethrel application upset endogenous PGR levels before VM acquisition and that this led to a delay in VM acquisition and subsequent hardening.

Table 7. The effect of applying Dropp (thidiazuron) or Ethrel (ethylene) as dormancy management tools on the caliper growth, fresh weight and winter kill of two-year old clonally propagated amur maples (*Acer ginnala*) grown at the Univ. of SK Plant Sciences (horticulture) plots.

Treatment	Fresh weight (kg)[a]	Pre-treatment caliper (mm) spring 1999	Caliper increase from spring 1999 to fall 1999 (%)	Caliper increase from spring 1999 to fall 2000 (%)	Winterkill (%) (1999/2000)[a,b]
Control	1.15	11.81	46.63	181.4	23.6
Dropp (0.05%)	1.00	11.99	51.30	173.3	56.5
Ethrel	1.02	11.95	47.89	184.8	41.7
Statistical analysis					
Significance[c]	ns		ns	ns	*
LSD	-		-	-	9.0
CV%	20.2		17.8	17.6	27.0

a – initial caliper measurements used as covariate in GLM analysis

b – percent data was transformed using the arcsine transformation method; non-transformed averages presented, but significance, LSD and CV% are calculated from transformed data

c – ns = not significant; * = significant at $p \leq 0.05$

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c – ns = not significant; * = significant at $p \leq 0.05$

Dormancy Management Discussion

The lack of positive results should not be viewed as waste of time and resources. Dormancy management is an important aspect in the production of woody ornamentals in our harsh environment. What this research has demonstrated is that growers cannot substitute a chemical quick fix for inappropriate management practices. What may work in more temperate climates such as BC or Oregon in terms of accelerated growth strategies must be tempered with the realization that those areas are not subject to the same short growing season or the extreme winter temperatures that occur in Saskatchewan.

Bibliography

Andrews, D. 1996. Dormancy in dogwood crosses. MSc Thesis, University of Saskatchewan, Saskatoon, SK, 177 pp.

Coleman, W.K. and E.N. Estabrooks. 1985. Chemical modification of cold hardiness in apple trees in eastern Canada. Can. J. Plant Sci. 65: 969-975.

Coleman, W.K. and E.N. Estabrooks. 1988. An evaluation of the effects of plant growth regulators on cold hardiness in apple trees. Can J. Plant Sci. 68: 859-869.

Coleman, W.K. and E.N. Estabrooks. 1992. Enhancement of cold hardiness in apple trees by paclobutrazol, thidiazuron and flurprimidol. Can. J. Plant Sci. 72: 1267-1274.

Coleman, W.K., E.N. Estabrooks, M. O'Hara, J. Embleton and R.R. King. 1992. Seasonal changes in cold hardiness, sucrose and sorbitol in apple trees treated with plant growth regulators. J. Hort. Sci. 67(3): 429-435.

Cook, J.A. and D. Boynton. 1952. Some factors affecting the absorption of urea by McIntosh apple leaves. Proc. Amer. Soc. Hort. Sci. 59: 82-90.

Crisosto, C.H., A.N. Miller, P.B. Lombard and S. Robbins. 1990. Effect of fall ethephon application on bloom delay, flowering, and fruiting of peach and prune. HortScience 25(4): 426-428.

Crisosto, C.H., P.B. Lombard, L.H. Fuchigami. 1987. Effect of fall ethephon and hand defoliation on dormant bud ethlyene levels, bloom delay, and yield components of 'Redhaven' peach. Acta Hort. 201: 203-211.

Crisosto, C.H., P.B. Lombard, L.H. Fuchigami. 1989. Fall ethephon delays bloom in 'Redhaven' peach by delaying flower differentiation and development during dormancy. J. Amer. Soc. Hort. Sci. 114(6): 881-884.

Fisher, E.G. 1952. The principles underlying foliage applications of urea for nitrogen fertilization of the McIntosh apple. Proc. Amer. Soc. Hort. Sci. 59: 91-98.

Friesen, L.J. and C. Stushnoff. 1989. Vegetative maturity of *Amelanchier alnifolia* Nutt. compared to red-osier dogwood and rescue crabapple. Can. J. Plant Sci. 69: 955-960.

Hare, P.D. and J. Van Staden. 1994. Inhibitory effect of thidiazuron on the activity of cytokinin oxidase isolated from soybean callus. Plant Cell Physiol. 35(8): 1121-1125.

Hill-Cottingham, D.G. and C.P. Lloyd-Jones. 1975. Nitrogen-15 in apple nutrition investigations. J. Sci. Fd. 26: 165-173.

Hubackova, M. 1994. The grapevine buds cold hardiness in juvenile plants. Ochrana Rostlin 30(4): 305-309.

Hutchinson, M.J., S.J. Murch and P.K. Saxena. 1996. Morphoregulatory role of thidiazuron: evidence of the involvement of endogenous auxin in thidiazuron-induced somatic embryogenesis of geranium (*Pelargonium* x *hortorum* Bailey). Plant Physiol. 149: 573-579.

Jalkanen, R.E., D.B. Redfern and L.J. Sheppard. 1998. Nutrient deficits increase frost hardiness in Sitka spruce (Picea sitchensis) needles. For. Ecol. Manage. 107(1/3): 191-201.

Kang, S., K. Ko and J.S. Titus. 1982. Mobilization and metabolism of protein and soluble nitrogen during spring growth of apple trees. J. Amer. Soc. Hort. Sci. 107(2): 209-213.

Khemira, H., T.L. Righetti and A.N. Azarenko. 1998. Nitrogen partitioning in apple as affected by timing and tree growth habit. J. of Hort. Sci. & Biotech. 73(2): 217-223.

Klein, I. and S.A. Weinbaum. 1984. Foliar application of urea to olive: translocation of urea nitrogen as influenced by sink demand and nitrogen deficiency. J. Amer. Soc. Hort Sci. 109(3): 356-360.

Klein, I. and S.A. Weinbaum. 1985. Foliar application of urea to almond and olive: leaf retention and kinetic of uptake. J. Plant Nutr. 8(2): 117-129.

Leece, D.R. and J.F. Dirou. 1977. Organosilicone and alginate adjuvants evaluated in urea sprays foliar-applied to prune tree. Commun. Soil Sci. Plant Anal. 8: 169-176.

Mok, M.C., D.W.S. Mok, D.J. Armstrong, K. Shudo, Y. Isogai and T. Okamoto. 1982. Cytokinin activity of N-phenyl-N-1,2,3-thiadiazol-5-ylurea (thidiazuron). Phytochemistry 21: 1509-1511.

O'Kennedy, B.T., M.J. Hennerty and J.S. Titus. 1975. The effects of autumn foliar urea sprays on storage forms of nitrogen extracted from bark and wood of apple shoots. J. Hort. Sci. 50:331-338.

Oland, K. 1960. Nitrogen feeding of apple trees by post harvest urea sprays. Nature 185: 857.

Oland, K. 1963. Responses of cropping apple trees to post-harvest urea sprays. Nature 198: 1282.

Paksasorn, A., M. Masuda, H. Matsui, H. Ohara, N. Hirata. 1995. Effect of fall ethephon application on bloom delay and fruit set in japanes apricot (*Prunus mume* SIEB. et ZUCC.). Acta Hort. 395: 193-200.

Price, C. and N.H. Anderson. 1985. Uptake of chemicals from foliar deposits: effects of plant species and molecular structure. Pestic. Sci. 16: 369-377.

Proebsting, E.L. (Jr.), and H.H. Mills. 1969. Effects of growth regulators on fruit bud hardiness in *Prunus*. HortScience 4(3): 254-255.

Proebsting, E.L. (Jr.), and H.H. Mills. 1976. Ethephon increases cold hardiness of sweet cherry. J. Amer. Soc. Hort. Sci. 101(1): 31-33.

Raese, J.T. 1977. Induction of cold hardiness in apple tree shoots with ethephon, NAA and growth retardants. J. Amer. Soc. Hort. Sci. 102(6): 789-792.

Raese, J.T. 1997. Cold tolerance, yield, and fruit quality of 'd'Anjou' pears influenced by nitrogen fertilizer rates and time of application. J. Plant Nutr. 20(7&8): 1007-1025.

Reif, H. 1978. Winter frost-hardiness increases with age. Deutsche Baumschule 30(8): 254-255. (abstract)

Rodney, D.R. 1952. The entrance of nitrogen compounds through the epidermis of apple leaves. Proc. Amer. Soc. Hort. Sci. 59: 92-90.

Rosecrance, R.C., R.S. Johnson, and S.A. Weinbaum. 1998a. Foliar uptake of urea-N by nectarine leaves: a reassessment. HortScience 33(1): 158.

Rosecrance, R.C., R.S. Johnson, and S.A. Weinbaum. 1998b. The effect of post-harvest foliar urea sprays on nitrogen absorption and partitioning in peach and nectarine trees. J. of Hort. Sci. & Biotech. 73(6): 856-861.

Ryadnova, I.M., Y.A. Volchkov, L. Titarenko and G. Ovchinnikova. 1974. Comparative study of varietal group, variety and age of trees as factors determining winter hardiness in peach. Nauch. tr. Maikop. st. VNII rastenievodstva (8): 115-118 (abstract).

Sanchez, E.E., T.L Righetti, D. Sugar and P.B. Lombard. 1990. Response of 'Comice' pear trees to a postharvest urea spray. J. Hort. Sci. 65(5): 541-546.

Schupp, J.R. 1993. Orchard mineral nutrition: ground-applied vs. foliar-applied fertilizers. Fruit Notes 58(2): 20-23.

Shadrina, L.S. 1980. The relationship between winter hardiness of apple cultivars and tree age. Sbornik Nauchnykh Trudov, Michurinsk (31): 3-8 (abstract).

Shim, K., J.S. Titus and W.E. Splittstoesser. 1972. The utilization of post-harvest urea sprays by senescing apple leaves. J. Amer. Soc. Hort. Sci. 97(5): 592-596.

Smithberg, M.H. and C.J. Weiser. 1968. Patterns of variation among climatic races of red-osier dogwood. Ecology 49(3): 495 – 505.

Stevenson, R.K. 1994. Dormancy and acclimation in dogwood clonal ecotypes. MSc Thesis, University of Saskatchewan, Saskatoon, SK, 159 pp.

Swietlik, D. and M. Faust. 1984. Foliar nutrition of Fruit Crops. Hort. Rev. 6: 287-355.

Thomas, F.M. and U. Ahlers. 1999. Effects of excess nitrogen on frost hardiness and freezing injury of above-ground tissue in young oaks (Quercus petraea and Q. robur). New Phytol. 144(1): 73-83.

Thomas, J.C. and F.R. Katterman. 1986. Cytokinin activity induced by thidiazuron. Plant Physiol. 81: 681-683.

Visser, C., J.A. Qureshi, R. Gill and P.K. Saxena. 1992. Morphoregulatory role of thidiazuron: Substitution of auxin and cytokinin requirement for the induction of somatic embryogenesis in geranium hypocotyl cultures. Plant Physiol. 99: 1704-1707.

Waering, P.F. and P.F. Saunders. 1971. Hormones and dormancy. Ann. Rev. Plant Physiol. 22: 261-288.

Wang, S.Y. and M. Faust. 1988. Changes in fatty acids and sterols in apple buds during break induced by a plant bioregulator, thidiazuron. Physiol. Plant. 72: 115-120.

Wang, S.Y., G.L. Steffens and M. Faust. 1986. Breaking bud dormancy in apple with a plant bioregulator, thidiazuron. Phytochemistry 25: 311-317.

Weinbaum, S.A. 1978. Feasibility of satisfying total nitrogen requirement of non-bearing prune trees with foliar nitrate. HortScience 13(1): 52-53.

Weinbaum, S.A. 1988. Foliar nutrition of fruit trees. *in*: Plant growth and leaf applied chemicals (P.M. Neuman, ed.). CRC Press, Boca Raton, FL, 178 pp.

Weinbaum, S.A., I. Klein, F.E. Broadbent, W.C. Micke and T.T. Muraoka. 1984. Use of isotopic nitrogen to demonstrate dependence of mature almond trees on annual uptake of soil nitrogen. J. Plant Nutr. 7(6): 975-990.

Zilkah, S., I. Klein, and S. Feigenbaum. 1987. Translocation of foliar-applied Urea ^{15}N to reproductive and vegetative sinks of avocado and its effect on initial fruit set. J. Amer. Soc. Hort. Sci. 112(6): 1061-1065.

Zybkova, N.F., Z.V. Bukashkina, Kh.A. Sharenkova and O.N. Kulaeva. 1983. Defoliating activity in substances of cytokinin type. Doklady Akedemii Nauk SSSR 272(4): 1011-1013. (abstract)

E. Personnel

Erl Svendsen (BSAg) has taken over the duties that were carried out by last year's technical research assistant and will manage the field and greenhouse portion of the trials as well as all reporting.

F. Expenses

See separate attachment